PYROTECHNY

OR THE ART OF MAKING

FIREWORKS

ILLUSTRATED

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Why ask for the moon
when we have the stars?

AS

Book A.

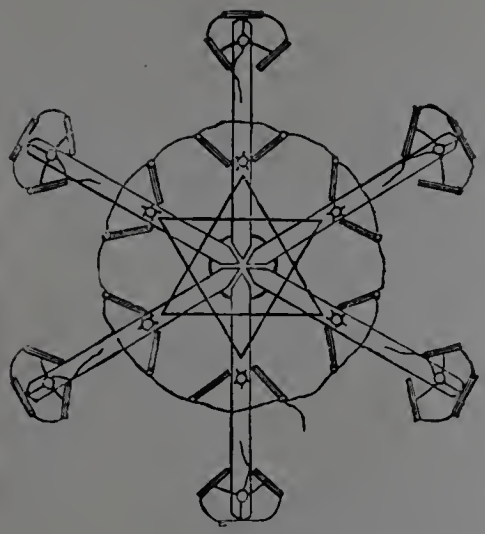
27/6/87

James Guiler.

July 1877

J. Gmelin

115



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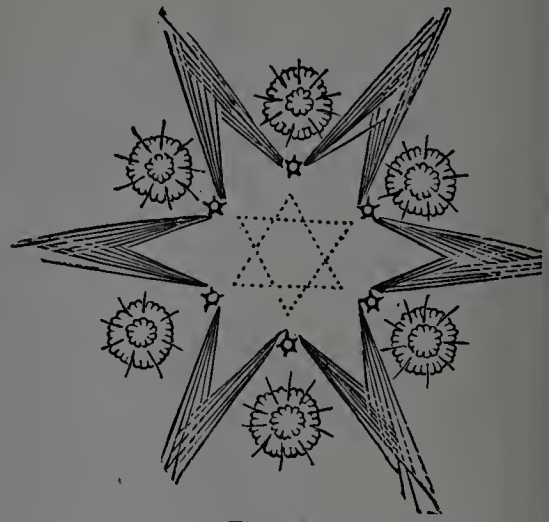

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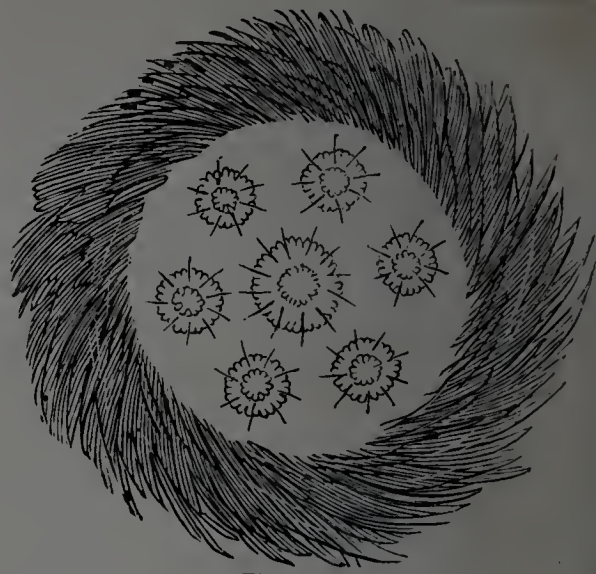

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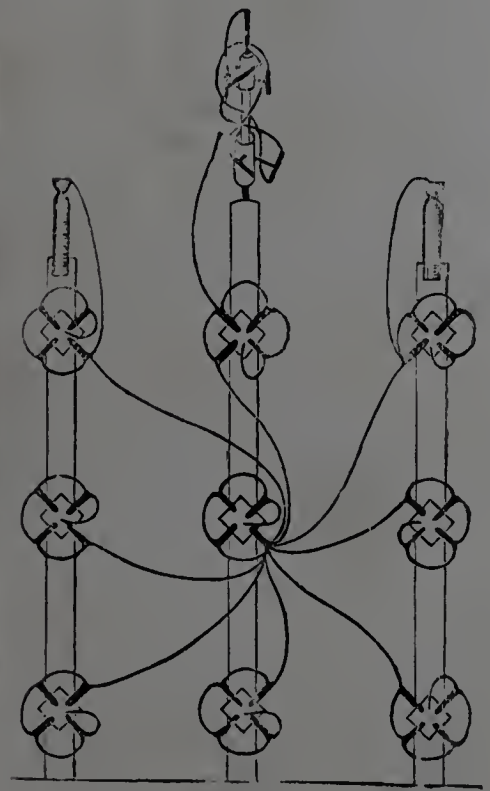

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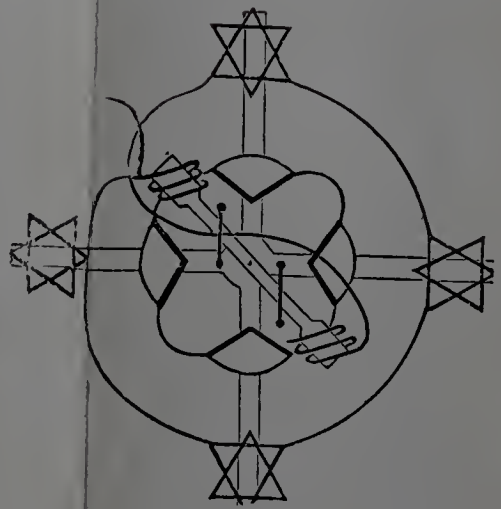

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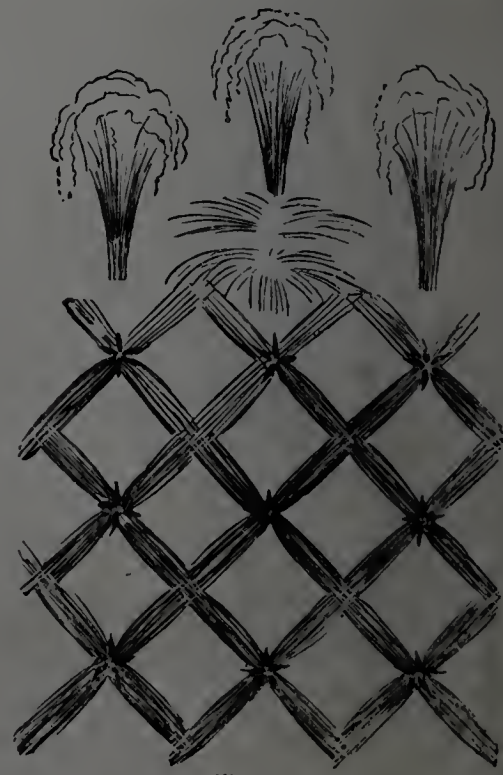

Fig. 122.

PYROTECHNY;

OR,

THE ART OF

MAKING FIREWORKS,

AT LITTLE COST,

AND WITH

COMPLETE SAFETY AND CLEANLINESS.

WITH

ONE HUNDRED AND TWENTY-FOUR ILLUSTRATIONS OF FORMS AND DIAGRAMS FOR MANUFACTURE AND EXHIBITION.

LONDON:
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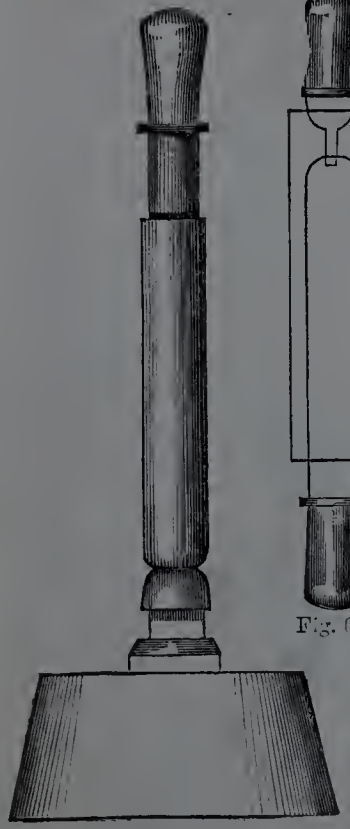

Fig. 12.

Fig. 10.

Fig. 6.

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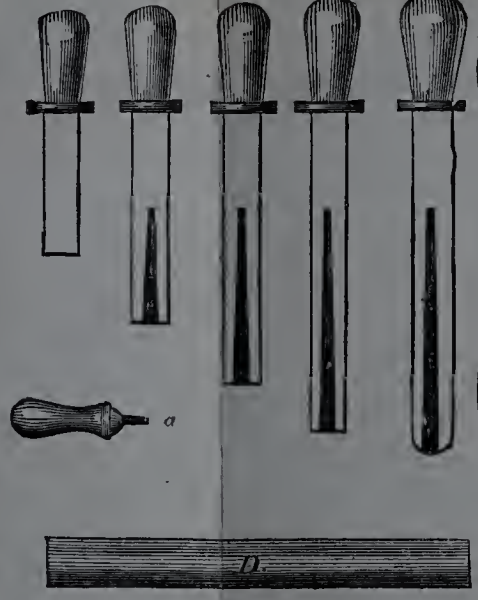


Fig. 17.

Fig. 23. 1oz.

Fig. 24. 2 oz.

Fig. 25. $\frac{1}{4}$ lb.

Fig. 26. $\frac{1}{2}$ lb.

Fig. 8.

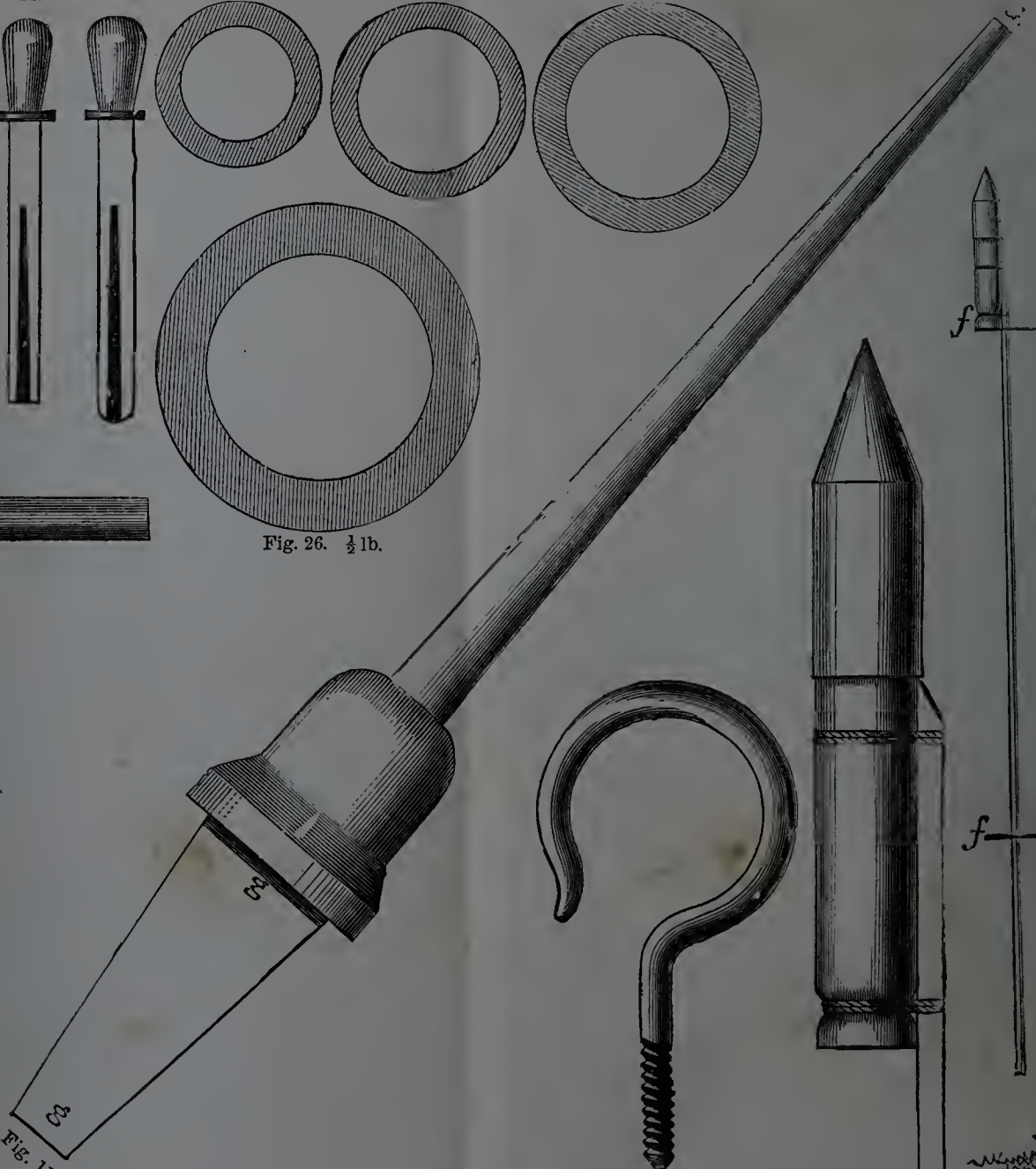


Fig. 11.

Fig. 29.

Fig. 27.

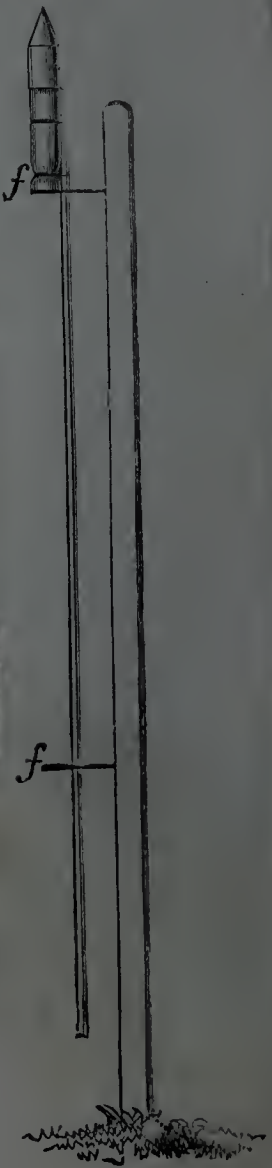


Fig. 28.

PYROTECHNY.

BY PRACTICUS.

PREFATORY REMARKS.

THE art of Pyrotechny has, like almost every other art in these days of experiment and research, undergone many processes of change and improvement. In fact, that part of the art which relates especially to the preparation of coloured fires may be regarded as entirely new; for not only has the danger which arose from the spontaneously-combustible nature of some of the old compositions for this purpose been obviated and removed, but many new colours have also been introduced (principally by the foreign artists), and the pyrotechnist is thus enabled to produce new combinations and contrasts, which twenty years ago were altogether unknown.

But, notwithstanding all this improvement and progress, it is a remarkable fact that no work has been published in England upon this subject since the year 1830. We have not even kept pace with neighbouring nations in this respect, for an excellent work has appeared through the French press, entitled, "M. Chertier sur les Feux d'Artifice" (the book, however, is now out of print, I believe), and there is also a very capital manual of the art in German, "Martin Websky's Lustfeuerwerkerei."

It is true that articles have appeared from time to time in encyclopædias and books of that class, but these for the most part have been copied out of one into another, and of all that I have been able to see the best are so condensed as to be to those uninitiated in the art simply unintelligible and useless, and to the initiated often very confusing. Moreover, the professional pyrotechnists have thrown no small mystery over their work, and have done a great deal to further the idea that the awful Promethean rites to which they have been admitted are not to be thrown open to ordinary mortals, and I cannot help thinking that they have thus thwarted the very interests which it was to their advantage to forward. Let any one only enquire of professional photographers whether the practice of their art by amateurs has injured their business, and has not rather increased the demand upon them; and I see no reason why the same should not be the case with Pyrotechny, though not, of course, to the same extent, because its study is never likely to become so popular.

The fact, then, that no work in English upon this subject has appeared during the last thirty years will, I trust, be regarded as a sufficient apology for the present publication. From its perusal, however, there will be derived nothing new to those who have already acquired a proficiency in the practice of firework-making, and, for aught I know, the professional pyrotechnist may even be puzzled by the absence of technical terms. But, on the other hand, I would have it understood that I am not writing with the purpose of describing for the benefit of little boys the mode of making squibs and crackers, nor am I going to tire my readers' patience, nor to consume my own time, by drawing up an historical account of the pyrotechnic art in its successive stages; nor is it my intention to enter into abstract and abstruse discussions upon the mathematical proportions proper

for the artist's tools and apparatus ; nor to trace, as has been so frequently done, the true and lineal pedigree of gunpowder. My object is simply this:—to furnish, for those who are unacquainted with the subject, such information as shall put them in the way of providing at any time for family parties, or school treats, an exhibition of fireworks, capable of affording an hour's real amusement to any number of people. I say to any number of people, because it costs no more to exhibit such a display to one hundred than to ten, and because I believe that it is difficult to find the person who would rather not see a good exhibition of fireworks, or who would stigmatise the hour spent in looking at them as "slow." It is evident that the public demand for exhibitions of this kind is greater and more widely spread than it was, and is still on the increase ; and the only wonder is that, under these circumstances, no more practical system of Pyrotechny should have appeared through the press. I am not saying that this work will supply the want that many have experienced, for it will be entirely elementary; but I hope at some future time to bring out a more advanced and extensive work, should I discover that anything worth calling an interest in my subject is abroad. This work, however, will be thoroughly practical, and that with the special object of showing how exhibitions may be provided at a little cost.

Now, there are three things which have been generally alleged and admitted as sufficient reasons against the practice of Pyrotechny; these are, danger, dirt, and expense. Upon each of these three subjects I will state what experience has taught me to be the truth.

First, as to danger. The explosion of firework factories from time to time has given a high colour to the risk which the public considers inseparable from any such manufacture. Some time ago I had the curiosity to inquire as far as I

could into the cause of these large explosions, and in no one instance could I discover that the accident arose from anything but carelessness on the part of workmen or some wilful and unwarrantable defiance of danger; and I am quite convinced that danger depends far more upon the operator himself than upon the materials used in his work. A barrel of gunpowder is not the thing one would choose for a seat while smoking a cigar or toasting a muffin; but be it remembered that there is no more danger to be apprehended from this barrel of gunpowder, when properly handled, than from a barrel of beer. And then, gunpowder is a material which the amateur will need only in very small quantities, being used far less than is generally supposed, and being only employed to give projective force or to make reports. Mealpowder, which is gunpowder in the state of dust and not in grains, is extensively used, but is in itself perfectly safe. Of course one can set fire to the one as easily as to the other, but why need it be dangerous on this account? There is nothing easier than to make the practice of Pyrotechny dangerous, but, at the same time, it is not only possible, but very easy, to manufacture fireworks without danger.

Now, as to the dirtiness of the work. It is generally believed that the making of fireworks renders cleanliness in the operator impossible, and is destructive of clothes on that account. Now, I maintain that cleanliness and dirt, as well as safety and danger, are mainly dependent upon the person, and not upon his work. He can fairly be called dirty only if he is never clean, or if he makes himself unnecessarily dirty. And so with the pyrotechnist. While handling such things as charcoal he does not expect his hands to be white, but he need not handle charcoal as if with the purpose of making his hands black. Every one must have observed how some people, in whatever they are engaged, in whatever they

undertake, will do their work cleanly and neatly, while others can do nothing without "making a mess." I myself have made the principal part of several exhibitions of fireworks, have mixed all the compositions, have done everything, in fact, except the actual ramming of the compositions into the cases, in my own sitting-room, which, I flatter myself, is as clean and tidy a room as one need wish to live in; and were it not for the presence of the boxes in which I keep my tools, &c., &c., no one, ten minutes after my work is over, would know what I had been about. This, however, I have only done for want of accommodation, for I would much prefer working in some out-house or room given up to the purpose where my apparatus would be less out of place as furniture, and where, instead of having to get out all my things afresh every time, I could resume my work exactly at the point where I had left it, for by this means a great saving of time would be effected. I would also strongly recommend to the beginner the use of an apron, and some holland sleeves to fasten tightly round the wrist and extend above the elbow, for many of the compositions employed are of a subtle and dusty nature, and will penetrate the clothes until the operator becomes accustomed to use them in such a way as shall not make them troublesome in this respect. I know, however, on the best possible authority—viz., that of experience—that fireworks can be made without detriment to clothes and without violation of cleanliness.

Expense now, in the third place, remains to be considered. It is, perhaps, not generally borne in mind that the reason why fireworks are expensive to purchase is that they take time to manufacture. The brown paper of which the cases are made, and the compositions with which they are filled, are of little value as compared with the time of the workmen employed. Now one supposes that if firework-making is

adopted as an amusement, there is sufficient spare time for its practice. But the amateur must not suppose that he can become proficient without some small outlay at the first; his tools and apparatus will cost him something, but when once procured they will enable him to make twenty exhibitions as well as one. And he will do well to bear in mind that if he will purchase such things of the persons whom I am about to recommend he will incur no unnecessary expense. He should also know what to order; and he will find that if he confine himself, as far as possible, to the manufacture of one useful size of each kind of firework, he will greatly diminish the number of tools necessary for making and filling his cases. Much expense will also be avoided by his purchasing the necessary chemicals, not in the smallest quantities procurable, this being the most uneconomical mode of purchase. I have avoided the employment of any of those costly preparations which have of late become known to the pyrotechnist, and are employed principally in the compositions for producing coloured fires; not, however, from any wish to ignore their excellence, but because I have been able to produce without them effects with which I have always been satisfied.

I shall now append a list of those fireworks the manufacture of which it is my intention to describe, and which in combination will be found to produce all the effects that the amateur need desire:—

Rockets, with heads of brilliant, tailed, and coloured stars, and golden rains.

Roman candles, with brilliant, blue, green, yellow, and red stars.

Gerbes and jets of brilliant, Chinese, and common fires.

Wheels of various devices, horizontal and vertical, plain and illuminated.

Bengal white and coloured slow fires for illumination.

Lances, white and coloured, for making up devices, such as names, crests, mottoes, wreaths, &c., &c.

Tourbillons, plain and brilliant.

Chinese flyers of different kinds.

Mines of serpents and crackers.

Brilliant suns, single and double, fixed and revolving.

Port-fires for lighting exhibition pieces, &c.

The pieces which I have enumerated above will furnish all the necessary elements of an excellent display. And I have no hesitation in saying that by careful attention to my directions all these pieces may be successfully made. I shall recommend nothing but what has been found to succeed constantly in my hands, and may, I am sure, be made to answer in the hands of others. I entirely disclaim, however, any attempt to describe the modes of manufacture adopted by the professional pyrotechnists. I know nothing of the secrets of their trade, nor have I any desire to acquaint myself with them; I only know that my own system of working never plays me false, however different it may be from theirs.

There are, however, a few things which I strongly recommend the amateur not to attempt to make, for the reason that their manufacture entails a considerable amount of tedious and uninteresting work, and they may be bought ready made of the professional pyrotechnists at a cost to which no one need object. They are such things as quick-match, mine serpents, and crackers, and pin-wheels, if indeed these are necessary.

I will now proceed to give an idea of the relative numbers in which the several pieces may be employed to form a good exhibition. This will, of course, be but a mere sketch or outline, intended to show how things, very simple in themselves, may be rendered very effective in combination:—

10 rockets: 3 of these with heads of brilliant stars, 3

with tailed stars, 2 with coloured stars, and 2 with golden rains.

10 Roman candles : 6 of these to throw brilliant stars, and 4 coloured stars.

12 wheel cases : 3 to make a single triangle wheel, 4 to turn an illuminated vertical wheel, and 5 to turn a horizontal mine wheel.

3 tourbillons : 2 plain and 1 brilliant.

A Prince of Wales feather, consisting of 3 brilliant jets.

A bouquet of Chinese gerbes.

2 white Bengal fires, 2 green, and 2 red fires.

2 cracker and 2 serpent mines.

And for a finale, some small device executed in lances, which shall change into a 5 or 8 pointed brilliant star or sun, accompanied with Roman candles, and a mine, either of serpents or crackers.

This is the kind of exhibition which my papers are intended to enable the amateur to make. The above list will be found to contain no lack of variety, which, in my opinion, is the great point to be kept in view.

In order that the reader of these papers may find no difficulty or hindrance in the way of his putting my directions into practice, I shall state farther on, where all the materials, chemicals, tools, &c., &c., which he will require, can be purchased ready for use, of a kind and quality that I recommend, and at a reasonable price.

But before concluding this part, I would impress upon the amateur the advantages to be derived from adopting a fixed plan of operations in preparing for his exhibition. If he would do his work well, he must learn to do it with the greatest economy of time, and labour, and material. He should first decide of what pieces his exhibition is to consist ; next he should get all his cases made, and remember that

these are not to be used until they are thoroughly dry, and that the more gradually and naturally they are allowed to dry the better they will be for his purpose. He should commence the filling of one kind of piece, and finish all of that species up to a certain point, before he begins upon any other kind. He should calculate the quantity of composition necessary for them, and not mix it until the cases are ready to receive it, and he has time to fill them. A very little practice will enable him to judge correctly the quantity necessary; but let him not hurry over this part of his work, for a very slight inaccuracy in reckoning the quantities of the several ingredients may spoil a large batch of composition. The old proverb, "The more haste the less speed," is at least as true in the practice of firework-making as in any other work. By mixing up no more composition than he really requires, he will both avoid waste and have no odds and ends of combustible mixture to take care of. He may perhaps think this piece of advice very unnecessary, but he will soon arrive at the conclusion that it is well worth his attention. Let him also bear in mind that he will require to get out as many tools for the making of one rocket as of ten, and that when he has them to his hand he cannot do better than finish the ten.

It is not, of course, to be expected that the amateur will at first fall naturally into the most easy and convenient methods of working, but every additional hour's practice will furnish some new experience, and he will soon discover that those operations, which at one time he considered the most troublesome and difficult, can be successfully performed in some very simple manner. He must never go to work under the idea that there is but one way of carrying out his plans; the exercise of a little thought on his part will generally unfold to him ways and means of accomplishing his object satis-

factorily and with ease. It is always best for each operator to establish his own mode of working, and not always to attempt to carry out details of manipulation which he sees described, under the impression that what is thus recommended is *the* way.

PYROTECHNY.

—o—

GENERAL OBSERVATIONS.

I MUST beg of you, kind reader, the privilege of addressing you no longer in the third but in the second person. By speaking to you, instead of about you, I shall avoid much circumlocution, and in words, at least, identify your interests with my own.

Since "generals" take the precedence of "particulars," before entering upon any description of the details of *rocket* apparatus or manufacture, I must introduce you to certain friends without which you will find it difficult to get on in your work, and with which I trust you will shortly be on excellent terms, for you will require their aid in almost every branch of pyrotechny. The tools peculiarly employed in each separate process of the art will be spoken of in dealing with that process, and in their own place; but a short account of the things that are *generally* requisite will be more in place here than in any other part of this work.

SCALES AND WEIGHTS.

1. In the first place, some are indispensable. The scales that

I use are of a very common make, with copper pans capable of holding about four ounces of nitre. These I have always found very convenient, and they are by no means expensive to buy; but I should think there is hardly a house where such a pair would not be found ready to hand. I use also, for purposes in which more delicacy and exactness is required, a pair of grain scales such as are employed by the apothecary. It is very important, particularly in the preparation of coloured-fire compositions, to be very exact in weighing out those ingredients which enter sparingly into the formulas, for a little more or less of these will often change entirely the character of the composition.

And now let me say a few words upon the subject of *weights*. The old books on pyrotechny did their best to confuse their readers in many ways, but in none more successfully than the following:—They insisted on giving their formulas in *weight*. For instance, they would tell you to mix together $3\frac{1}{2}$ oz. of one ingredient, 2 dwt. of another, 1 scruple of another.

Now the ordinary way in making up such a receipt would be by employing one weight out of three distinct tables, for the ounce usually employed in commerce is the avoirdupois ounce; the pennyweight is only found in a table used for weighing precious metals and precious stones; the scruple only in a table used by a compounder of medicines. Now I intend to avoid all confusion of this kind by the simple plan of giving my formulas in *parts* and not in weights. For instance, in writing down the formula for gunpowder, I should put it in the following manner:—

Nitre	70 parts.
Sulphur	15 „
Charcoal	15 „

So that, whether you take it in grains or in tons, the formula is equally intelligible, and you get at one glance a true idea of the relative proportions of the ingredients. But, although I mean to keep weights out of my formulas, we cannot dispense with them in our work. Now, if you would save yourself much trouble and inconvenience, procure, in addition to your ordinary grain weights, a 2 oz., a 1 oz. and a $\frac{1}{2}$ oz. *troy* weight. This ounce contains precisely the same number of grains as eight of your apothecary's drachms and as twenty-four of your apothecary's scruples — that is 480 gr., whereas the avoirdupois ounce contains only 437$\frac{1}{2}$ gr. And by this means you will avoid much confusion and save much time in your calculations; because you will have all your smaller weights convenient aliquot parts of the greater; and, if I mistake not, you will find these extra weights very handy for other than pyrotechnic purposes.

Next, I wish to caution you against an injudicious employment of the pestle and mortar. These auxiliaries are not intended for any other purpose but the reduction to powder of lumps, crystals, &c.; they are never properly used for *incorporating* ingredients. *Large* quantities of pyrotechnic compositions are always *mixed* in a sieve; *small* quantities are best mixed by stirring them about with a spatula upon a piece of paper. A pestle and mortar is a species of apparatus which I rarely use, for I procure my various salts, &c., in the form in which they are ready for use, and I strongly recommend you to do the same, feeling that you will soon be convinced of the convenience of such a plan. Remember, too, to keep your powdered ingredients in well-corked or stoppered bottles, for the reason that some of them are very deliquescent, and are utterly unfit for pyrotechnic purposes except when perfectly dry. The four following things, however—nitre, sulphur, charcoal, and meal-powder—which are not

subject to injury from a slight exposure to the air, and which will be required in larger quantities than other things, I always keep in tin canisters, such as are made to hold a pound of coffee. A piece of sheet copper about six inches long, bent into the form of a shallow boat or scoop, will be found useful in taking these things out of their canisters to be put into the scales and weighed.

SIEVES.

2. Now with regard to SIEVES: you will require two of these, with brass-wire bottoms; one of the fineness of twenty meshes to the inch for *mixing*, which, for distinction's sake, I will call *the mixer*; the other of forty or fifty meshes to the inch for *sifting*, and to which I shall refer as the *sifter*. These sieves are made with a receiver and a top, so that by their means you can sift or mix any compositions, however subtle or dusty may be their nature, without the slightest inconvenience or annoyance. I may as well here mention that I use the 20-mesh mixer for *sifting* the *coarse* charcoal employed in my rocket compositions, but all other sifting is done by the 40-mesh sifter. The size of those which I use is about six inches in diameter, and I think you will find this large enough for every purpose, as you will not be likely to want to mix or sift any very large batches of composition at a time. These sieves, made of any size or design that you please, may be procured of Mr. Darby, 98, Regent-street, Lambeth, London, at whose shop you will also find many other handy little articles, such as horn or copper scoops, spatulas, &c.

Fig. 37.

Fig. 39.

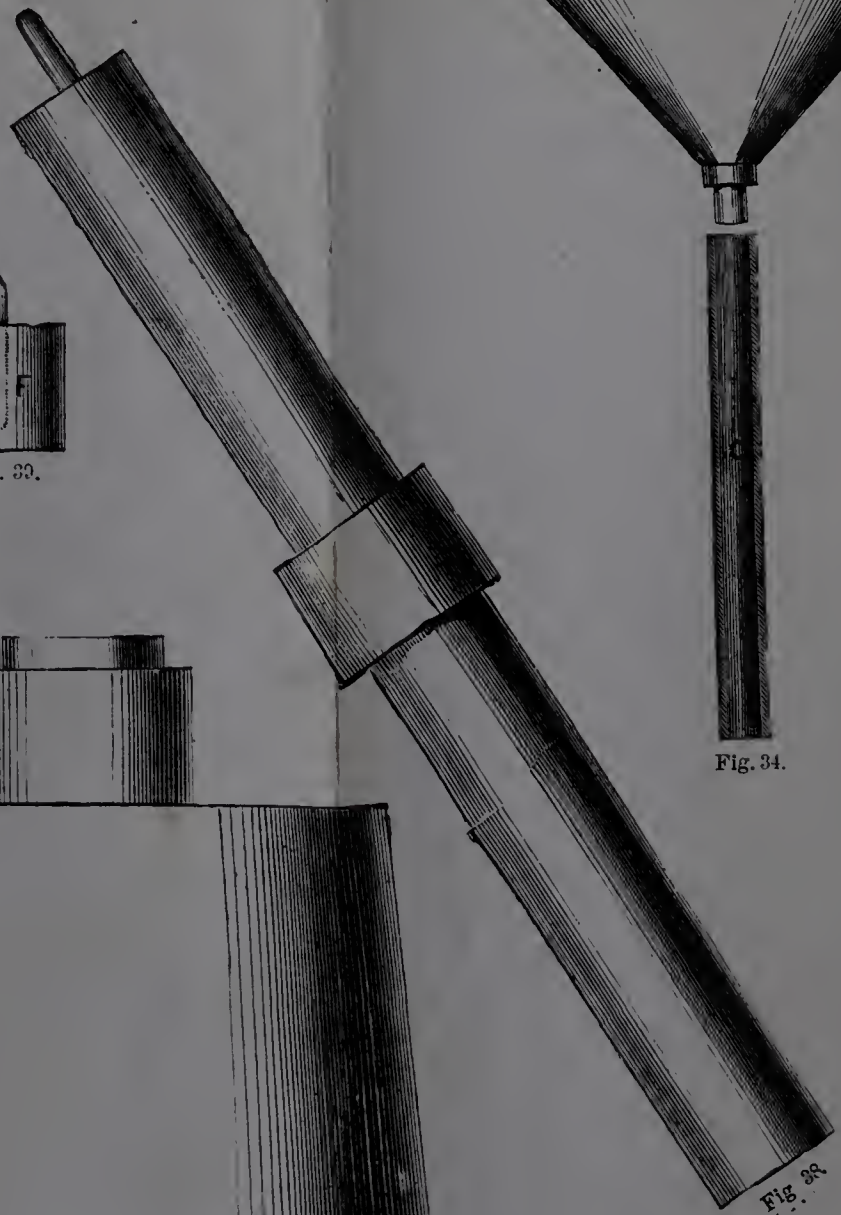


Fig. 38.

Fig. 34.

Fig. 35.

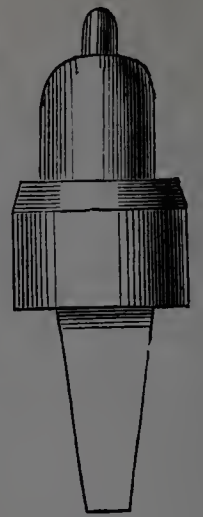


Fig. 46.

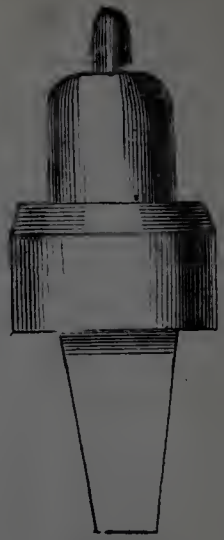


Fig. 45.

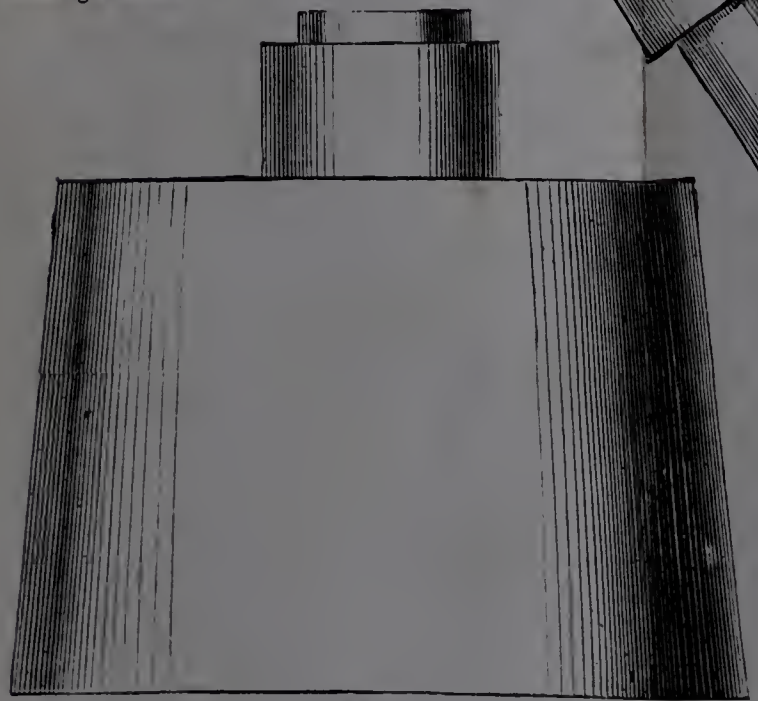


Fig. 40.

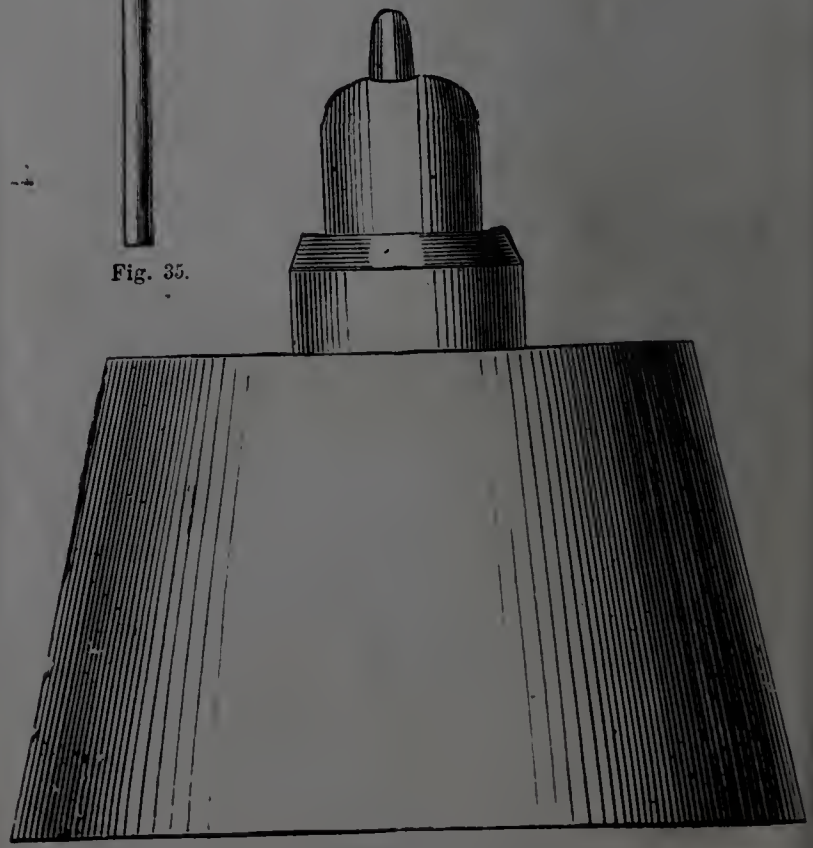


Fig. 44.

MANUFACTURING.

ROCKETS.

3. Having now cleared our way of these necessary preliminaries, we may at once proceed to speak of the manufacture of ROCKETS; first, of what a rocket is, and then of how it is made. There is nothing like starting with a good distinct notion of what we have to make before we set to work to make it. It is said of a person who was asked by his friend to give him a logical definition of a house, that he at once replied that "*it was a thing with a chimney;*" which definition, being equally applicable to a moderator lamp and a steam-engine, can hardly be considered exhaustive in the case of a house; and, in like manner, if we start with the idea that a rocket is *a thing that goes up in the air,* we shall not have any very tangible model of rocket excellence before us as a guide in our work. It is, however, very true that some rockets which we see can only be properly and faithfully described as things which go up in the air, for they no more deserve the name of a rocket than does a child's kite or a cock-sparrow, either of which would come equally well under the above definition. But let us see whether we can arrive at something a little more accurate. A rocket we will define as *a species of firework which, when properly fastened to a stick of a certain size and weight, suspended with its mouth downwards, and ignited, ascends into the air by the force of its own combustion, rises majestically to its proper height, throwing out, from the beginning to the end of its course, a rich and uniform tail of sparks, and at the extreme range of its flight giving birth to a cluster of stars, or shower of fiery rains, or other decorations, as they are called, which should burn long enough to be well seen, and not disappear almost at the moment of their appearance.* This is what every rocket should be when fired;

and let me beg of you not to stop short of attaining this excellence, for perseverance will give you experience, and with the aid of these two you need despair of nothing. When I had been puzzled and misled by all the books and information on the subject that I could procure, and had met with nothing but failure in all my attempts, I set myself to work to make my own experiments in a new direction, on the supposition that I understood, to a certain extent, the principle on which success depended. And well do I remember my delight at seeing a rocket of my own production scramble up into the air in a very undignified and disorderly manner, and there perform certain nervous evolutions which I will defy any pen to describe or pencil to depict. But although its performance was erratic and laughable, I had conquered; the key from that moment was in my own hands; and soon, after careful consideration and a few more experiments, I managed to produce a rocket of which I saw no reason to be ashamed.

I have stated above what appearance a good rocket should present to the eyes of a spectator when fired; I am now about to state what appearance it should present to its manufacturer before being fired—in fact, what it is that he has to make. *It is a strong cylindrical case, made of pasted brown paper and imperial board, contracted near one of its ends in order to form a narrow aperture, and filled with a certain composition in such a manner that a long narrow cavity is left in its centre, extending almost throughout its whole length.* This is what I shall call the rocket, for the ascending power lies solely in this part; the head, being an after-addition, will be spoken of it in its proper place, and not allowed to interfere here. In the annexed woodcut A A represents the exterior diameter of the case; B B, the interior diameter of the same; C C, the long cavity extending from the mouth up the centre of the composition, which cavity is called the

"soul" of the rocket; D D D, the composition with which the remainder of the case is filled. The lower of the two C's represents the mouth, or "choke" as it is called, at which all the combustion that goes on in the rocket has to find its vent. When a light is applied to the mouth of the rocket, the whole surface of the soul of the rocket is set on fire at once, and on this depends its power of ascent; for so large a quantity of fire having to make its escape through so narrow an aperture and meeting with considerable resistance from the external air, makes the rocket recoil in a direction opposite to that of its mouth, until all the combustible material which it contains is consumed. This is a broad outline of the principle upon which rockets ascend. It will be unnecessary for me to dive deeper into theories here, for I am sure that you will be anxious for me to come to practical details without further delay.

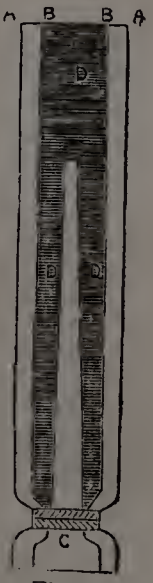


Fig. 1.

Among other things in my prefatory remarks I stated that firework-making need not be an expensive recreation, but you must bear in mind that nothing is easier than to make it expensive, and that we must adopt some strictly economical system of operation. Since rockets are the most scientific of all fireworks, and the apparatus necessary for making them is more costly than that for making any other kind of firework, we must do all that we can to bring their manufacture within reach of the amateur. There are many books, and I dare say many persons, that will tell you that you cannot hope to produce a good rocket unless you have a mould proper for the purpose made either of gun-metal or of some hard wood. I believe that I am right in telling you that

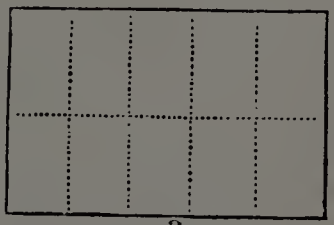
such a piece of apparatus varies in cost from 3*l.* to 10*l.*, but I also know that I am right in assuring you that a rocket, in every respect equal to many that are rammed in a mould, may be produced without this expensive luxury. I can only say that I *never* use a mould, and my belief is that the workmen employed by professional pyrotechnists are, for the most part, only too glad to dispense with its use, for it is of importance to them to ram the greatest possible number of rockets in a given time, and if they were to be delayed by having to unscrew and screw a mould before and after filling each case, half their time and its value would be lost to them. I use, and recommend you also to use, a simple steel spindle let firmly into a wooden block, and if your cases are made strongly enough you will be able to produce all that your ambition will picture to you by means of this inexpensive apparatus, and without the help of the mould.

But before we speak of the size and proportions of this spindle it will, of course, be necessary for us to determine the size of the rocket which we intend to produce. Now, the rocket that I recommend you to make, as being the most generally useful and economical, is that which the professionals call the $\frac{1}{4}$*lb. rocket.* You will bear in mind that this name is not intended to signify that the rocket when finished will weigh a quarter of a pound, but that its interior diameter is equal to the exterior diameter of a leaden ball weighing 4oz. You will find, I am sure, that the capabilities of this size of rocket, when properly made, will satisfy you for all ordinary purposes, and, taking this for granted, I shall now proceed to speak of this particular size only, in order to prevent the possibility of confusion.

ROCKET CASES.

4. The first thing that you have to do is to make the case.

Do not hurry over this part of the process, for more depends upon it than is generally supposed. It is made in the following manner :—Procure some imperial board (which is a kind of thin paste-board made of two sheets of brown paper pasted and pressed together; also some stout Kentish brown paper of such a substance as will weigh 70lb. per ream. Now fold a sheet of the imperial board down the middle of its length, thus : —



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Cut it along this fold, then divide each of these halves crossways into five equal parts and cut them apart. Each sheet will thus furnish enough board for ten $\frac{1}{4}$lb. rocket-cases. This board is only made in one size. Now take a sheet of the 70lb. brown paper, divide it into halves at its natural fold, and then divide each of these halves crossways into four strips. One of these, together with one of the strips of imperial board, will be sufficient to make one case. I have given you above the directions for cutting your paper and board without waste; you will, however, find it more convenient to buy them ready cut up; it will save you time and trouble, and will occupy much less space among your stores. They can be procured of Mr. W. H. Darby, 98, Regent Street, Lambeth, London, and he will supply them ready cut if you only state for what purpose they are intended.

The "former," on which the board and the paper are to be rolled, is simply a piece of brass tubing, about 12 in. long, and $\frac{3}{4}$in. in diameter. This you had better procure of the person whose name I shall mention presently, when I speak of apparatus, and to whom I recommend you as a maker of all pyrotechnic *tools*, except such things as the sieves, &c., above mentioned.

I must not speak about the pasting and rolling of the cases until I have said a few words upon the subject of the paste itself. It is a great mistake to have your paste made thick; you will gain nothing by doing so, and you will find it very troublesome to use. It should be made of such a consistency as will admit of its being spread very readily upon the brown paper, &c., and by being tolerably fluid will saturate it much more thoroughly; and this, after all, is what you want to do, for the hardness of the finished cases depends far more upon the complete saturation of the paper than upon the thickness of the paste between its layers. The brush, which you will find convenient, is one about 2in. in diameter, and can be procured of Mr. Darby. Into each pint of paste, while boiling, put a large teaspoonful of powdered alum; this will have the effect of keeping your paste sweet and free from mouldiness for weeks, and will also prevent it from becoming watery, which it would otherwise do in a few days.

I will now suppose you to have your paper, imperial board, paste, and brush ready to hand. You will next require some kind of slab on which to paste and roll your cases. For this purpose I use one of the largest common roofing slates that can be procured: its size is 24 by 12in. This makes a cheap and very serviceable pasting-slab if its surface be only moderately smooth.

Now we come to the actual rolling of the cases. First paste all over one side of one of the strips of 70 lb. brown paper; then take one of the strips of imperial board, and fold one end of it once round the brass tubular "former." Hold this, thus folded, with your left hand, and paste over all the rest of the upper side of the strip with your right. Then roll it up, as straightly and as tightly as you can, till all but about 3 inches of it is wound upon the "former."

Upon these projecting 3 inches lay the end of the strip of brown paper, with its pasted side upwards, and then roll it till both board and paper are neatly and closely wound round the "former." You will find at first a little difficulty in getting the strips to roll up straight, but a little practice will overcome this. You will now require what is called a "rolling board," that is, a piece of common smooth deal board about 20 inches by 8 in size, with a wooden handle screwed on its upper side at one end (see fig. 3). Then with the left hand take hold of the end of the "former," which projects out of the case, loosely, so as to allow it to revolve in the hand, and with the right hand roll case and "former" from one end of the slate slab to the other between it and the rolling board, pressing upon the latter, and using it as a carpenter does his "trying plane;" and by this means the same effect will be produced upon your newly-made case as is produced upon linen, &c, by a mangle. These directions read, no doubt, as if they belonged to some very complicated operation; but let me assure you that it is one far easier to perform than to describe. Some modification of this plan will in all probability suggest itself to your mind as an improvement upon it; for there are few people who do not after a few trials fall into some method of working which, besides answering their purpose, has the additional merit of being peculiar to themselves. I may as well mention here that the quickest way of making cases is to paste all your strips of paper and board before you begin to roll any of them, taking care not to paste that part of each strip of board which is to make the first turn round your "former."

3.

In the next place, when you have made as many cases as

you require, the operation of "choking," or forming their mouth and neck, remains to be done, and is to be accomplished in the following manner:—Procure some strong close string about one-eighth of an inch in diameter; take about one yard of this, and tie one end of it to a ring or nail which has been driven very tightly about 3 feet from the ground into a wall, beam, or tree, and the other end of this string tie firmly round a stout piece of stick or ruler about 18 inches long. Now take the round-ended drift (fig. 4), and insert this into one end of your cases till its rounded end appears about an inch from the other end, leaving, in fact, an inch at one end of the case unoccupied by the drift. Then take the little "choking piece" (fig. 5), and insert its metal point into the hollow end of the drift. This operation is illustrated at fig. 6. Now rub your string well over with yellow soap; the more thoroughly this is done the better. Then pass the stick or ruler between your legs in such a manner that by leaning backwards you can make the string very tight; but before tightening it give the soaped part of the string one turn round the part of the case marked *c c* (fig. 6), then by leaning backwards you will contract that part of the case until you leave an aperture only large enough to admit the point of the "choking piece." As soon as this is done tie some string tightly round the neck thus formed, to prevent its becoming larger. The best knot for this purpose is the one given at fig. 7. Then, when you have drawn out your choking piece and drift, the proper name of which latter is "*the setting-down piece*," your case must be put by to dry thoroughly before use. The apparatus given at fig. 8 is very convenient for choking cases quickly, and is given in case you should think

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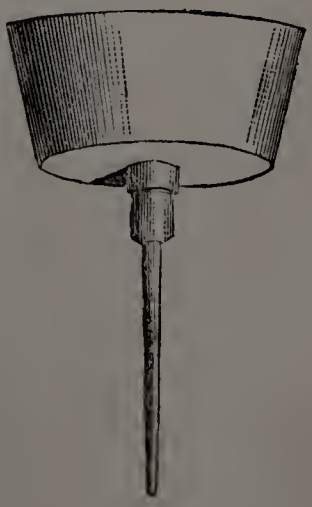
it worth while to make such a thing. Any boy with a fair notion of carpentering would find no difficulty in making it. It is simply a string passed over a small wheel and fastened to a pedal which works on a hinge close to the ground. A glance at the diagram will show you that by putting your foot upon the pedal *f* the string may be drawn very tight. The case is choked at the point marked F. No choking can be done except while the cases are wet.

Now, supposing that you can do nothing else until your cases are dry, I will, meantime, introduce you to some of your tools. Fig. 9 represents the block and spindle over which your rockets are to be rammed. The case of the rocket is forced, mouth downwards, over this spindle by inserting into it the setting-down piece (fig. 4), which you have used before, and giving the handle of this some blows with the mallet (fig. 10). This operation has the effect of enlarging the choke to its proper size, and of making the mouth of the case very smooth and hard. The diagram (fig. 11), represents the steel spindle and nipple in its proper size. The part marked *g g* is driven into the wooden block which forms its foot. Fig. 12 represents the rocket-case driven down upon the nipple when ready to be filled with its composition. Figs. 13, 14, 15, are three drifts of different lengths, pierced so as to admit the steel spindle, and to be used for driving the composition into the cases round the spindle. They are used in the following manner:—A ladleful of the composition is put into



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the case, and then driven down with the longest of these drifts by the mallet; then another ladleful driven with the same. Then a shorter drift is taken for the next few ladlefuls; then the shortest, till the case is full up to the top of the spindle. Then the unpierced drift (fig. 15) is used to ram in some composition solid, and to drive some clay upon the top of this. This operation will be described much more minutely in its proper place. Fig. 17 represents the "former" on which the cases are rolled.

These tools may be procured at a very reasonable price of Mr. Newman, 4, Augustus Street, Regent's Park, London.

Having made you slightly acquainted with the various tools and apparatus to be used in making and filling rocket-cases, it will now be necessary for me to say a few words about their size and proportion, for much will depend upon accuracy in this particular. I have given you a sketch of four drifts to be used in loading your cases with composition. The longest of these I shall call *the first;* and the shortest, which is the solid one, *the fourth;* this being the order in which you will have to use them. The measurements that I am now about to give have reference only to *the straight part* of the drifts, not taking their handles into consideration. The length of the first drift is 6 inches; second, $4\frac{1}{2}$; third $3\frac{1}{4}$; fourth $2\frac{3}{4}$. The first three of these drifts are pierced or hollow, in order to admit the steel spindle over which the rocket is rammed. The first should be pierced to the length of 4 inches; second, $2\frac{1}{2}$; third $1\frac{1}{2}$.

Taking the exterior diameter of $\frac{1}{4}$ lb. rocket to be about 1 inch—and this measurement is near enough for our purpose—the former on which the cases are rolled should be $\frac{3}{4}$ of an inch in diameter, and the drifts about $\frac{1}{4}$ of an inch in diameter. The "former" should always be slightly larger in diameter than the drifts, because the paper that

is rolled upon it is thoroughly wetted with the paste, and in drying will shrink a little; and, therefore, if your drifts be of the same size with your former, you will find considerable difficulty in getting them in and out of your cases; they ought to be a good easy fit. Twelve inches you will find a convenient length for your former.

In case you should wish to prepare rockets of other sizes, and in order that you may readily see the relative magnitude of cases of such sizes as are generally used in the art of pyrotechny, I here append a table:—Those which are called

1 oz. cases are about $\frac{1}{2}$ inch bore.
2 oz. ,, ,, $\frac{5}{8}$,,
$\frac{1}{4}$ lb. ,, ,, $\frac{3}{4}$,,
$\frac{1}{2}$ lb. ,, ,, 1 ,,

In following the directions which I gave in my last paper for cutting up your imperial board and 70 lb. brown paper for rocket-cases, you will find that the case produced will not be a very stout one. Although I have made an excellent rocket in a case of such a thickness, you will, perhaps, find it advisable to use more paper and board, and prepare a thicker case. For this purpose cut your board in the manner that I have described before for your 70 lb. brown paper—that is, into *eight* equal strips—and then cut each of your sheets of brown paper *lengthwise into four* equal strips. By this plan you will be able to make very stout cases, which will not be at all liable to injury during ramming; and thus one sheet of board, with two of brown paper, will furnish eight $\frac{1}{4}$ lb. rocket-cases. You must bear in mind when choking them to contract the aperture till it is considerably smaller than you will eventually require it to be. The setting-down piece (fig. 4) has two uses: it is employed first in choking the case, and afterwards in driving or setting it down, when choked, over the steel

spindle. The reason for driving the case thus down till the mouth is brought close to the nipple at the foot of the spindle is that the choke or aperture may thus be left of the proper size. This proper size is about two-fifths of the inner diameter of the case; and the aperture left immediately after choking should not be much more than one-fifth of the same inner diameter. The operation of "setting down" the cases is performed best, in my opinion, when they are perfectly dry and immediately before they are filled.

ROCKET COMPOSITION.

5. Now supposing your cases to be thoroughly dry and ready to be charged, the next thing that we must consider is the composition with which they are to be filled. Judging from the effect produced by rockets prepared by different makers, I should imagine that the formulas for their compositions are of almost endless variety. Some seem to prefer a very quick composition, which will raise the rocket to a great elevation in a very short time; others, one which will produce a large and rich tail of sparks not ascending so fast or so high. In my opinion, the mean between these two extremes is decidedly preferable: that which I aim at in rocket manufacture is to produce a very high, but not a very rapid, ascent; and when this my object has been properly gained, I have never had any fault to find with the tail of sparks which is thrown out. I may say, without any exaggeration, that I have experimented upon several hundreds of different compositions, varying first one ingredient and then another, increasing or decreasing them by very gradual steps, until I have come to the conclusion that the two following are the only ones worth retaining. But it must be remembered that it is not enough to have a good formula

or two in order to be successful, for much will depend upon *the manner in which*, and *the care with which*, these are made up :—

No. 1.

Nitre	16 parts.
Sulphur	4 „
Charcoal	8 to 9 „

This, I believe, is a very old formula, and, provided the charcoal be properly prepared, may be found very useful and effective. I used this receipt for a long time, and thought it incapable of improvement, until, from a wish to try the effect of the addition of a little meal-powder, I came by chance upon the following, which I do not think can be surpassed :—

No. 2.

Nitre	16 parts.
Sulphur	3 „
Meal-powder	4 „
Charcoal	8 „

Now let me tell you that the success of rocket compositions depends upon two things—the intimate union of their ingredients, and the fineness or coarseness of the charcoal. Such charcoal as you can procure at a chemist's ready pounded will be of no use whatever to you, for it is in far too fine a state of subdivision. You will require a much coarser charcoal for the most part, and one not of the same coarseness or fineness throughout. If you could make a mixture containing charcoal of three different degrees of fineness—the first moderately fine, the next in pieces of the size of grains of ordinary sporting gunpowder, and the third of the size of large poppy seeds—and take equal parts of each of these three you will find that you have a mixture very serviceable for rocket purposes. But you can procure of Mr. Darby, whom I have mentioned before, a mixed charcoal which will save

you the trouble of sifting. I recommend you, however, to use no charcoal that will not pass readily through your 20-mesh mixer, for your object is not to have your charcoal in large pieces, but to have a certain proportion of it coarser than the rest. You will find that the larger your proportion of coarse charcoal is, the slower your composition will be, and, within certain limits, the more fine charcoal you employ, the quicker it will be. Now, as the sparks produced by coarse charcoal remain visible in the air much longer and are much larger, than those produced by fine charcoal, I think it advisable to employ a good proportion of the coarse and in order to make up the strength that the composition loses by this plan, I take a smaller proportion of sulphur, as you will see by comparing formulas Nos. 1 and 2, and at the same time add a certain quantity of meal-powder. All these ingredients may be procured of Mr. Darby. The mode of mixing them is as follows:—Weigh out your quantities of nitre, sulphur, and meal-powder, mix them well together, and pass them through your 40-mesh sifter. This you will have no difficulty in doing, because the condition in which you purchase them is one of fine powder; your meal-powder especially cannot be too finely sifted for this purpose. You will find it a great convenience to add to this mixture a few drops of methylated spirits of wine or gin—a very slight quantity will suffice to render it less dusty—but you must bear in mind that whenever either of these liquids is employed, the composition will be sure to rust the steel spindle around which it is driven, unless you take the precaution of rubbing it over with a little oil or grease after using and before putting it away. Next add your charcoal. Stir the whole together, and pass the mixture two or three times through your 20-mesh mixer; by this means it will be thoroughly incorporated and fit for use.

ROCKET RAMMING.

6. Now we come to the actual ramming of the rockets; and, unless you intend to be a great nuisance to your friends and neighbours, you had better not dream of performing this operation indoors, it being productive of much noise and jarring; and you will find that they will not take much interest in your pyrotechnic progress when they have been annoyed and deafened by your frantic efforts for their amusement. You had better choose, therefore, some place either out-of-doors, or in an outhouse, where you are not likely to be interrupted or interfered with; the outhouse, of course, will be preferable, because there you will not be exposed to wind and weather, the former of which, especially, is often a source of considerable inconvenience when working out-of-doors. But whatever place you decide upon, you must have a very solid block of some kind, which is better made either of wood or stone, and must be set upon, or let into, solid ground. I should think that you will find no difficulty in meeting with one, made of either of these materials, in any carpenter's or builder's yard; odd pieces of stone and timber which would answer your purpose may generally be procured for a few pence. The stone block which I use is about 12 + 8 + 8 inches. On your block I recommend you to put nothing but the wooden block into which your spindle is fixed. The composition which you are using should never be placed upon it, because it is sure to become to some extent unmixed by the concussion caused by the blows of your mallet, for the particles of any coarse ingredient which it contains will find their way to the surface. You will find it advisable to have your block, and the table on which your tools and composition are placed, of such a height from the

ground that, in working, you need not stoop or put yourself into any uncomfortable attitude.

Next we have to consider what is the most convenient receptacle for your composition while your cases are being filled with it. I use a copper scoop capable of holding about 8 ounces of composition, made something like an open coal-scuttle in form, which I have always found very convenient, and which is represented in the annexed woodcut (fig. 17).

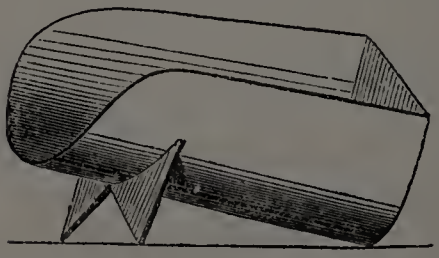


Fig. 17.

You will next require a small ladle made of thin copper or brass, of such a size that it will take up just as much composition as you should put into your case at a time, and will admit of being passed into the case. By means of this you will be able to drive in the composition very uniformly, for by giving a certain number of blows of a certain power to each ladleful, you can be sure of an equal compression throughout the length of the case. Such a ladle Mr. Newman will supply with your rocket tools, of the right size for filling $\frac{1}{4}$ lb. cases.

I will now suppose you to be ready at the ramming-block, with all your tools about you, your composition ready, and your case driven firmly down over your spindle. I strongly recommend a slight moistening of the composition as directed above before you begin to ram it. Now, taking the longest of the drifts (fig. 13) in your left hand, insert into the case when the first ladleful of composition has been put in. You are not to suppose that by "a ladleful" I mean as much composition as can be heaped up upon the ladle or scoop, but as much as will lie within it after you have passed the drift over its surface, and have levelled the

composition to the height of its sides. To this first ladleful of composition give *fourteen* blows with the mallet: it is not necessary to exert much force in this operation, for the weight of the mallet will be nearly enough to do the work for you; and you will find that after each stroke the mallet will recoil with the blow to a point almost high enough to be the starting-point for the next stroke. Having given the proper number of blows, take another ladleful of composition, and when you have put it into the case, drive it down in the same manner as the former one with the same number of blows. Then for your third ladleful take the longest drift but one, which must be used for this and the following ladleful, giving to each of them *sixteen* blows. Then take the shortest hollow drift, and use this for as many ladlefuls as will make the composition rise to the top of the steel spindle, giving eighteen blows to each of them. Then by inserting the short, solid drift, you will be able to measure the distance between the top of the spindle and the top of the case. When you have taken this measurement, make a mark, on *the outside* of the case, which will show you how high the spindle rises on the inside. By adopting this plan, or any other that may occur to you as simple, you will always be able to ram the same quantity of solid composition above the spindle. This is really an important matter, and one on which depends mainly the beauty of your rocket's performance when it reaches its greatest elevation in the air. There are great varieties of opinion as to what should be the quantity of composition rammed solid above the spindle, and it is a much more common matter to find too little than too much composition used for this purpose. The effect of using too little is, that the rocket does not fairly arrive at its turn before its stars or other decorations are thrown out. This, in my opinion, is a considerable fault; for it robs the rocket of a

great deal of the elegance of its flight, and gives one the idea that it is in a hurry to get its work over. Nothing but actual experience and observation will enable any one to decide which he considers the proper quantity of solid composition. I consider the best length for this part of the rocket to be that of *the exterior diameter of the case*—that is, an inch or rather more for rockets of the $\frac{1}{4}$lb. size. Larger rockets, I have always found, do not require quite so much in proportion; smaller rockets rather more. You should give twenty blows with the mallet to each ladleful of this solid composition. I am well aware that this number of blows sounds like a great deal of hard work, but you may rest assured that these twenty blows, given as I have directed above, will occupy only five or six seconds of time, at the cost of very little exertion.

Having now completed the ramming of the composition into your case, you will next require some common potter's clay in dry powder; this can be procured of Mr. Darby in a condition proper for use. Take half-a-ladleful of it, and ram it down very hard upon the top of the composition with the solid drift. This clay when thus compressed will form an end to your rocket nearly as hard as stone—not so hard, however, but that you can bore a hole through it about 5-16ths of an inch in diameter, which will allow of the necessary connexion between the rammed composition and the stars or other contents of the head of your rocket. In the next place I will speak of the

PRIMING.

7. This may be done in two ways; for exhibition purposes I should merely put into the mouth of the rocket some meal-powder-paste made as follows:—Make a rather soft, but not too liquid paste, by moistening meal-powder with gum-

water made of the strength of 2 oz. of gum-arabic to a pint of water. With the flattened end of a stick rub some of this paste into the cup formed at the choked end of the rocket, taking care that none of it *is left in the choke* or narrow aperture at which the fire from the rocket has to find vent; for, if any should remain there, the rocket when fired is almost certain to burst. Any of the paste that happens to be forced into this aperture may easily be taken out afterwards by means of a piece of wire or stout pin.

Your rocket is now finished as far as its ascending power is concerned.

ROCKET POT.

8. I will tell you my method of making the head, or *pot* as it is termed, of the rocket. You must have a piece of hard wood turned of a shape like that indicated in the following wood-cut (fig. 18). The straight part of this should be about 4 inches long, and a shade larger in diameter than the exterior of your rocket-case — that is, about $1\frac{1}{8}$ inch in diameter, if you adopt the method of cutting up your imperial board and 70 lb. brown paper given in *this* chapter. Now take some moderately thick brown paper, and cut it into strips about 5 inches in width and 8 in length; each of these strips will be long enough to go twice round the *pot-former* described above. When you have pasted as much of each strip as will not lie actually against the former, roll it up straightly and pinch in one end; you will thus have made a cylinder of paper (fig. 19) closed at one end, the other end of which will fit nicely over the clay end of

Fig. 18.—Pot-former.

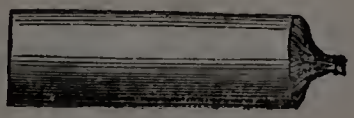


Fig. 19.—Rocket-pot.

your rocket. This is the pot of the rocket, which is to contain your stars, rains, &c.

ROCKET CONES.

9. You will next require a turned wooden former on which you can make paper cones of such a size at their base that they can be neatly pasted on to the top of your pots—that is, the base of these cones should have the same diameter as the pots. Although such conical caps are by no means necessary, yet they are a very great assistance to the rocket in its ascent, enabling it to rise with much less resistance through the air. The cone-former is represented in the annexed wood-cut (fig. 20). To make these cones upon it, cut out as many circular pieces of brown paper as you require, the semi-diameter of which must be slightly greater than the height of the cones that you have to make. Then cut or tear these circles into halves and paste them on one side. Now place the first half-circle upon the former, pasted side outwards, taking care that the apex of the cone beat the point marked A in fig. 21. Then fold the brown paper neatly round the cone-former, and when you have made it to sit as closely to it as possible, proceed in the same manner with the other half-circle, putting it upon the first, pasted side inwards. The paper cones thus made must next be covered

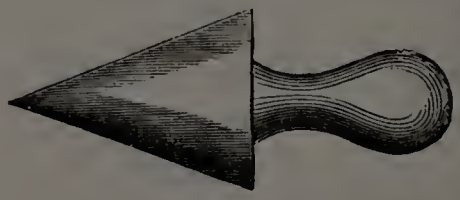


Fig. 20.—Cone-former.

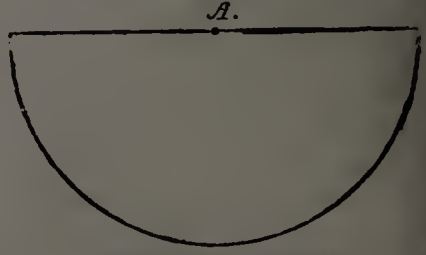


Fig. 21.—Paper for Cone.

with one thickness of thin paper cut large enough to extend ½ an inch or rather more beyond the open end of the cone, and this projecting part, when notched all round with your scissors, can be pasted down round the top of the rocket-pot. When this is done the pot will present the appearance of annexed illustration (fig. 22).

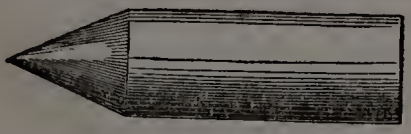


Fig. 22.—Pot, with Conical Cap.

ROCKET STARS.

10. When all the pasting that has been necessary in making the pots is thoroughly dry, the filling them with stars is all that remains to be done for the completion of the rocket. You will find that the ¼lb. rocket will carry an ounce of stars well. After weighing out your stars, then, into parcels of this weight, empty one of these parcels into each pot. You will next require some sort of powder to strew among the stars which shall have the effect of igniting them and at the same time of bursting the pot. I have always found meal-powder by itself to be too rapid in its explosion to convey the fire to all the stars; many of them are blown out of the pot, never taking fire at all. The mixture which I should recommend you to use is the following:—

Meal-powder	6 parts.
Fine charcoal	1 part.

Charcoal added to the meal-powder in the above proportion will render its combustion slow enough to light all the stars, without being too slow to burst the pot. Of this mixture take a ladleful (I mean the ladle which you use in filling your cases), and put it with the stars into the pot, which must now be securely glued over the clay end of the rocket-case.

ROCKET STICK.

11. Lastly the rocket-*stick* remains to be considered. This appendage is used for the purpose of keeping the mouth of the rocket *downwards*, so that if it move at all its motion must be an upward one. The rule for telling whether the stick be of the proper weight or not is the following:—After having tied it on to the rocket in the manner indicated in the page of illustrations, ascertain whether it will balance if laid across the finger about 2 inches from the mouth of the rocket. If the stick forms an exact counterpoise to the rocket at this point, it will answer your purpose very well. The length of the stick which I use for $\frac{1}{4}$ lb. rockets is 4 feet, and its size about $\frac{3}{8} \times \frac{1}{2}$ inch. The best wood for these sticks is American pine. It is very light, and should be free from knots. You will be able to procure them much cheaper of Mr. Darby, and much more uniform in their make, than of any carpenter. In some old treatises upon pyrotechny you will find recommended a tapering rocket-stick, to the *large* end of which the rocket is tied. I have never found any advantage which these sticks possess over those that are of one size throughout; and I think I may say that no professional pyrotechnist uses tapering rocket-sticks. On the annexed page of wood-cuts (figs. 23 to 26) I have given you a sketch of the rings which I use, through which the rocket-stick must be passed, and from which the rocket is to be fired. These rings should be screwed into an upright post (fig. 27) standing 5 feet out of the ground; the upper ring near the top of the post, the lower about 3 feet from the ground. There is also a sketch (fig. 28) to show you how the rocket is to be suspended on this post.

I have stated above that there are *two* ways of priming rockets; the one used for exhibition purposes I have already

described. Rockets thus primed are fired by applying a lighted port-fire to their mouth. The other method I have found very convenient when making trials either of rockets or of stars, for it enables you to get some distance from the rocket-post before the rocket rises, and consequently to gain a much better view of the object of your experiment. It is done in the following manner:—Paste or tie a piece of touch-paper round the mouth of the rocket which shall project an inch or rather more beyond the mouth. Then take a piece of uncased quick-match about $2\frac{1}{2}$ inches long, and put it into the soul of the rocket, leaving so much of it outside the choke as can be twisted into the projecting part of the touch-paper. If this is done so as to leave a short twist of touch-paper beyond that part which contains the quick-match, you will gain a short interval of time between the moment of lighting the rocket and that of its ascent.

You can procure of Mr. Darby the cases *ready made*, and, in fact, anything employed in firework manufacture; but I strongly recommend you to learn to make the cases yourself, as you will then be not only much more independent, but also much more economical in your work.

Let me recapitulate a little, and add a few hints to remind you of certain points important in rocket manufacture.

Do not hurry over any part of the work, either the making the cases or the composition, or the ramming of the rockets.

In moistening your composition with spirits of wine or gin, be careful to add very little of the liquid, and to stir the composition about *very thoroughly* until all the moisture that is present is very equally diffused.

Remember that the addition of nitre or meal-powder to your composition will render it more rapid in combustion; the addition of sulphur or charcoal more slow. By this means you can vary the strength of your rocket composition

to any degree which proves successful or satisfactory in your hands.

By no means forget to bore a hole through the clay at the end of your rocket, and thus to form the communication with your stars.

Never allow your steel spindle to become rusty. Every coat of rust that you have to scour off from it diminishes the size of the spindle.

Remember that the work that is done neatest is always done best.

ROCKET STARS (How to Make).

12. By following a few simple directions for the manufacturing of these, you will be able to vary almost to any extent the heads of your rockets, and to produce combinations according to your taste and fancy.

The stars that are used as decorations to the different species of fireworks are of various kinds, sizes and shapes, according to the purpose for which they are intended.

1st. The ordinary rocket-stars, which are called "brilliant" or "bright," are made in small cubes. Their composition is moistened with gum-water, and while moist flattened to the thickness required. It is then scored or cut across with a knife, and allowed to dry. When dry it can be easily broken up into cubes at the places where it was divided by the knife. *Tailed* stars are also made in the same way and of the same size.

2nd. Roman candle stars are small cylinders of composition made of a size proportioned to that of the case out of which they are to be thrown.

3rd. *Coloured* rocket stars are made by driving the coloured composition, slightly moistened, into small cases,

which go under the name of *pill-box cases.* If the star is to consist of one colour only, these pill-boxes are open at both ends, and a piece of quick-match is placed between the composition and the inside of the pill-box, and allowed to project about half an inch beyond each end of it. When fired, these stars burn at both ends at the same time, and so produce a great amount of fire in proportion to their size.

If it is required to make stars consisting of more than one colour (in which case they are called "changeable stars"), the pill-boxes are left open at one end only. The composition is thereby prevented from burning at more than one of its surfaces at a time. These stars generally contain *two* colours; the pill-boxes are half-filled with one coloured composition and the remaining space filled with another. These changeable stars burn much longer than the others, and therefore produce a more beautiful effect; but being larger they require to be used in larger rockets, the *half-pound* size being the smallest that is adapted for this purpose.

GOLDEN RAIN.

13. There is another and exceedingly beautiful decoration for rocket heads which is called golden rain. This is by no means a difficult thing to make. Some small paper cases are made, about 2 inches long and of the size of goosequills; these are filled with a sparkling composition and primed with wetted gunpowder. They are placed, mouth downwards, in the head of the rocket, and arranged in such a manner that they may *all* be ignited. At the bursting of the rocket, they will describe a series of beautiful ringlets of sparkling fire.

I have now enumerated as many different kinds of stars,

&c., as will provide you with the means of producing any amount of variety. I now come to the details of the manufacture of these decorations. We will begin with the ordinary

BRILLIANT STARS.

14. First, let me impress upon you the necessity of seeing that *all ingredients used in star compositions are in as fine a powder as possible.* You cannot have them too fine or too well incorporated and mixed. The following is the formula which I employ for the

COMMON BRILLIANT STARS.

Nitre	16 parts
Sulphur	8 „
Sulphuret of antimony . . .	4 „
Meal-powder	3 „

Let all these ingredients be in fine powder, and, having carefully weighed out the quantities, mix them thoroughly. Next, take some gum-water of the strength previously mentioned—viz., two ounces of gum-arabic dissolved in a pint of warm water. Spread your star composition upon a piece of zinc plate or slate, and add to it a little of the gum-water at a time, taking care to stir the composition about *well* till all the moisture is equally diffused through the whole. It is not necessary that this composition should be made *wet,* but only something like brown sugar in moistness, so that it will *bind well* when pressed together. When you think this is sufficiently done, roll or press the composition into a flat shape like a thick pancake, and make it as square, or, at all events, as rectangular, as possible. Its thickness should be about *a quarter of an inch.* You will find a large spatula a very convenient tool in this operation, both for flattening the cake of composition and for getting it into a

convenient shape. Now take your spatula, and with it score the composition across both ways, so that you have it divided into a number of little cubes, fig. 30.

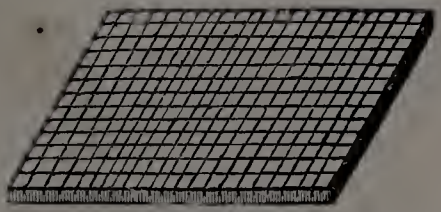


Fig. 30.

It may then be set aside to dry in a warm place; it will be forty-eight hours before it is fit for use in summer, and about a week in winter. When dry you will have no trouble in separating the cubes at the marks left by the spatula.

I may as well, however, introduce you to a simple piece of apparatus which will enable you to perform this operation much more comfortably and cleanly. I have a small wooden tray made of mahogany, six inches square, and three-quarters of an inch deep, *inside measurements*. Into this I place a flat piece of wood, which fits very easily into the tray, and is half-an-inch thick. This acts as a *movable false bottom*. It will be readily seen that when this false bottom is in the tray, placed upon the other bottom, *the tray will be filled up so as to leave a depth of a quarter of an inch only unoccupied*. This space I fill with the moistened star-composition, having first rubbed the surface of the false bottom with soap to prevent any adhesion taking place between the composition and the wood. Having now pressed into the tray as much composition as will fill it to the height of its sides, I score it with the spatula as directed above. A large hole is made in the *natural* bottom of the tray, so that I can, by putting my fingers through it, raise the false bottom covered with stars out of the tray. I then place a piece of cardboard or zinc on the top of the stars and turn the false bottom upside down. The stars will be found to separate from the wood very easily, and may be left to

dry on the zinc. The tray is then ready for another batch of stars.

The advantages of this plan are, that there is no trouble in getting the composition into a uniform, convenient shape and thickness; that the composition requires much less gum-water; and that, consequently, the process is a quicker and a cleaner one.

TAILED STARS.

15. The same plan may be adopted also for the making of *tailed stars*, with a slight variation which I now proceed to describe. These stars are not moistened with plain gum-water, but with a mixture of gum-water and linseed-oil. The gum-water should be of the strength given above, and should be made *quite hot* by placing the bottle which contains it in a jug of boiling water. When it is sufficiently hot, *to every 8 ounces of gum-water add 1 ounce of linseed-oil.* Shake the bottle till these are thoroughly mixed, *and no oil can be seen.* Use the moistening fluid, *while* hot, in the same manner as directed above for brilliant stars. The following is the composition for

TAILED STARS.

Nitre	16 parts.
Meal-powder	12 „
Antimony (sulphuret)	8 „
Fine charcoal	4½ „
Sulphur	4 „

If the above directions are carefully followed out, you will have some stars which are exceedingly beautiful in their effect, and by no means difficult to make. At its first appearance the star has nothing remarkable in it but the rapidity of its combustion. When this, however, is over, a

kind of boiling lava is formed which remains red-hot for a long time, and which, in its descent to the earth, takes the appearance of a glowing drop of golden fire, followed by a tail of sparks, remaining visible till it reaches the ground. I think the proportion of linseed-oil given above will not bear being altered without detriment to the performance of the stars. *If less oil is used, the stars assume their tailed form sooner, and disappear sooner; if more,* they will reach the earth before their principal and characteristic beauty is seen.

Both "brilliant" and "tailed stars" may be made in cubes whose sides are about a quarter of an inch. On account of the presence of the oil, "tailed stars" take a longer time to dry than "brilliant." An advantage which they possess, besides that of superior beauty, is that they are much more sure of ignition than brilliant stars.

I may as well mention here that a tray for forming the stars, such as I have described above, and of the size given above, will contain about 8 or 9 ounces of composition at a time.

COLOURED STARS.

16. We now come to the very important subject of *coloured* stars. These require considerable care in their preparation, the beauty of their performance depending entirely upon the *uniform fineness, the intimate union, and the dryness of their ingredients.* If you wish to make these coloured stars with any degree of satisfaction to yourself, keep the various preparations which enter into their composition *always ready for use*—that is, *in fine dry powder*, preserved in well-corked or stoppered bottles. There is one chemical salt which requires

especial care in keeping, on account of its deliquescent properties—that is, of its tendency to attract moisture from the air; and unless this salt, which is *the nitrate of strontia*, be thoroughly free from moisture when used, it will produce no effect at all, except a needless waste of chemicals. I must therefore tell you that the formulas which I am about to give you will fail most entirely in your hands, unless you are very particular in this matter of dryness. Over and over again have I been led to condemn formulas for coloured stars and fires as useless or imperfect, for the sole reason that I did not then know how their ingredients were to be handled, and what care was necessary for the production of their intended effect.

In the first place I strongly recommend you to attempt to make no coloured stars *for rockets, except such as are made in the pill-box cases,* of which I have spoken before. These pill-boxes are made in the following manner:—Procure a piece of *straight* iron rod, 12 inches long, and from three-eighths to half-an-inch in size; the usual size for this "former" is about seven-sixteenths of an inch. Now cut some cartridge-paper into strips about 8 inches wide, and from 9 to 10 inches long; paste these strips all over, and roll them round the iron rod closely and neatly. When this is done, remove the case thus formed from the rod without tearing or breaking it, and set it aside to dry. When dry it will be very hard and stiff. It can then be cut, by means of a very sharp knife, into little lengths of half-an-inch each. These lengths are the open pill-boxes, into which your composition is to be rammed for *coloured rocket-stars*.

In order to accomplish the filling of these cases with the least amount of trouble, procure a piece of stick, of a convenient length, and of such a size round that it will pass *easily* into the pill-boxes. Next take a small piece of quick-

match, about $1\frac{1}{2}$ inch long, and pass it through the pill-box in such a manner that it may project beyond each end about half-an-inch (see Fig. 31). You will be able to steady the pill-box while filling it by holding it by these two ends of quick-match. The composition pressed into these boxes is always slightly moistened; and by this means, when once dry, will not be liable to be shaken out again. In making, however, any trials of your coloured star compositions *for your own satisfaction* before making a large batch of stars, you had better press the composition in *dry;* by this means you will be able to see at once what their performance is worth.

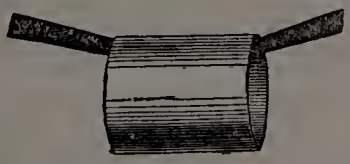


Fig. 31.

The fluid that I employ for moistening these coloured compositions is a solution of shellac in methylated spirits of wine. As shellac enters into the composition of many of these colours, it will not be necessary to make your solution a strong one. It should be of the thickness of the ordinary spirit varnishes, such as photographers use for coating their negative pictures. The exact strength is not a matter of any great importance, as long as you do not make the solution too rich in shellac; for by doing this you will impair the purity of your colour to some extent.

Remember that you must make these compositions *wet*. A very slight moistening is sufficient to make them *bind* well when pressed into their cases.

The first colour of which I shall speak will be the red, or crimson. It is in the preparation of this colour that you must be most careful about *dryness*.

CRIMSON STARS.

17. The composition which follows is, in my opinion, the best for

CRIMSON STARS.

Chlorate of potash. . . .	24 parts
Nitrate of strontia. . . .	32 „
Calomel	12 „
Sulphur	6 „
Shellac	6 „
Sulphide of copper . . .	2 „
Charcoal (fine)	2 „

This composition gives a magnificent deep crimson when burnt *at night.* Do not be disappointed, if, in your experiments *in the day-time,* the colour should not appear very deep.

Remember that there are two kinds of colours in pyrotechny, and that beyond a certain point it is impossible to amalgamate their respective qualities. The first of these two kinds is the colour *which has a considerable depth of tint, but which has not much reflective or illuminative power.* The other kind is that *which has a very decided, but not so deep, tint, and which is capable of surrounding itself with a luminous atmosphere of colour during its combustion—in fact, which has great brilliancy and power of illuminating objects.* Now the *last* of these two kinds is the proper one to be employed for star purposes. We should never desire to produce a shower of dead-looking stars, however intense their colour might be. It is also an ascertained fact that the colour of stars always *appears deeper when seen from a distance.* Do not then be disappointed, I repeat, if the colour appears somewhat weak when you are making a trial of your composition *just under your eyes in the day-time.*

Now, with regard to the crimson star composition above, remember that I only say that it is one that succeeds *in my hands*. You may, perhaps, think it too rapid in its combustion, in which case you can increase the proportion of calomel, or decrease that of the chlorate of potash. The calomel has the effect of deepening the colour, but at the same time of retarding the combustion, and of weakening the illuminative power. The shellac must be in as fine a powder as possible; it has the effect of producing a rich, thick flame, and also of rendering more sulphur unnecessary. It also enables the composition, after having been wetted with the above fluid, to harden into a mass tolerably impervious to moisture. The sulphide of copper is used for the purpose of giving a very slight bluish tint to the flame, and thereby of neutralising any yellow that might impair the purity of the crimson, arising from impurity of the chemicals.

You should keep all these ingredients ready powdered, dried, and sifted through your 40-mesh sifter; and then, when you require stars, you will having nothing to do but to weigh out the proportions given in the formula, and mix them on paper with a spatula. The more you handle the nitrate of strontia, or any composition containing it, the moister it will become, and the less effect it will produce. Therefore do not think of mixing the ingredients till you are ready to make your stars, and have a convenient, dry, warm place in which to stow them when made.

You can procure the things mentioned in the above receipt, and, in fact, those required for all the coloured compositions, of Mr. Darby, 98, Regent Street, Lambeth.

But, in case you may think it desirable to prepare and dry your nitrate of strontia yourself, I give you the following directions—

Procure a common earthenware pipkin, or, still better, a

glazed iron frying-pan of a convenient size. Into this place your nitrate of strontia in rough crystals. One or two pounds will be sufficient to prepare at a time. Place the vessel on a clear fire, but do not make it too hot. There is not the slightest danger of explosion, as this salt cannot be induced to burn except in combination with other things. You must now boil, or rather stew, the crystals in their own water of crystallisation. The heat will soon cause them to run into a thick pulpy mass. When in this state, they must be *constantly stirred,* or upon the evaporation of the moisture they will resume a crystalline form. This you wish particularly to avoid, as your object is to get this mass into *powder.* Continue then to stir it with a stick or flat piece of wood until the moisture is driven off by the heat, and the salt remains in the condition of a white dry sand. A few trials will enable you to perform this operation in such a manner that after it the strontia will be ready at once for use. If, however, enough stirring did not take place, you will find some fused lumps among your dry preparations; these must be pounded in a mortar, and afterwards dried.

The operation described above is very simple, and does not take long to perform. No strontia can be used for coloured stars or fires *unprepared.* If, after keeping the dried nitrate of strontia for some time, you find that it is again becoming moist, it may be re-dried, either in the vessel used above, or in an open dish placed in a well-heated oven. This operation is proper also for the preparation of the nitrate of baryta.

For the solution of shellac you will find the following plan a convenient one:—Make a very strong solution of the resin in methylated spirit of wine, which shall be as thick as treacle. As you require your thinner solution for moistening coloured star compositions, dilute a portion of the thicker solution with the methylated spirit to the strength required.

The sulphur used in all coloured compositions should be as free as possible from acid; otherwise, when mixed with chlorate of potash, it may be dangerous. If you have any doubt about it, wash the sulphur in a solution of common potash in water, and dry it gradually. The acid will be entirely neutralised by this plan. Never think of pounding sulphur and chlorate of potash together; they form a detonating compound which will explode with friction or percussion.

The compositions that I here give for colours are *perfectly safe* when made as I direct. I have made coloured stars from them, and placed these stars at the side of a fireplace till they have become so hot that I could not bear them in my hands, and I have subjected them to several tests, all of which they have stood well; and I think I may safely recommend them to you as not at all liable to spontaneous combustion or possessed of any dangerous quality. I must tell you, however, that *they may be heated till they explode*, but it is *quite unnecessary and very foolish* to expose them to any high temperature at all. In drying them, a good plan is to put them in front of a fire in a flat tin box, which will prevent any chance of their being ignited, and will at the same time keep them in a thoroughly dry atmosphere till they become perfectly hard. The box may be placed about two feet from the fire, so that it becomes moderately warm.

In filling the pill-boxes with composition, put a piece of quick-match through them, as directed above, and hold them by the two projecting ends of match. Let a short groove be cut in the side of the stick with which you press in the composition, large enough to allow it to pass the quick-match without injuring it.

ROSE-COLOURED STARS.

18. I now give you a composition for producing

ROSE-COLOURED STARS.

No. 2.

Chlorate of potash . . .	20 parts.
Carbonate of strontia . . .	8 ,,
Calomel	10 ,,
Shellac	2 ,,
Sulphur	3 ,,
Charcoal (fine)	1 part

The advantage of this composition is that it is not at all liable to suffer from damp in winter. The carbonate of strontia is a salt not deliquescent like the nitrate, and is, moreover, always to be had in a state of fine powder. The colour procured by the above formula is not so deep as that which the first composition will produce; but it is especially beautiful when contrasted with an intense blue. If its combustion should be thought too rapid, less of the chlorate of potash may be employed. It is to be moistened with the solution of shellac.

GREEN STARS.

19. Our next colour will be the green. I have especially observed that stars of this colour always appear far more intense when burning at a distance than when close to the spectator. The colour produced by the nitrate of baryta is never very deep where any great rapidity of combustion is required. It is, however, an exceedingly pretty tint, and is seen to its greatest advantage when used in contrast with a rich red. I employ the following formula for

GREEN ROCKET STARS.

No. 3.

Chlorate of potash . . .	20 parts.
Nitrate of baryta	40 „
Calomel	10 „
Sulphur	8 „
Shellac	3 „
Charcoal (fine)	1 part.
Sulphide of copper . . .	1 „

The composition made according to this formula will produce a colour which leaves nothing to be desired, if the several ingredients be only *in fine powder, dry, and pure.* It is not affected by moisture nearly so much as any composition containing nitrate of strontia. The shellac employed should be as fine as possible. And here let me remark that the reduction of shellac to powder is a process of itself; no coarsely-powdered shellac will answer your purpose. Mr. Darby will supply you with it in *fine* powder quite as cheaply as you can get it done elsewhere. Composition No. 3 is to be moistened with the solution of shellac. The sulphide of copper you may have some difficulty in procuring. You are sure, however, to meet with it at the shop of Messrs. Bolton and Co., 146, Holborn Bars, London, but you must ask for the *fused* sulphide of copper, for there is a *precipitated* sulphide also, which is of no use to you. Do not use any of it that will not pass through your 40-mesh sifter. I add this ingredient rather as an improvement than as necessary to the composition. You may substitute for it, if you please, the preparation of copper which I am about to recommend in the composition for blue stars. If composition No. 3 should be thought too fierce, try the addition of a little more calomel.

PALE ROSE-COLOURED STARS.

20. The next formulas that I shall give are two which I have occasionally used and found effective. Their merit is that they possess a very intense illuminative power; their colour, however, is not so intense as that of those which I have already given. They have also the advantage of being very readily ignited, but care must be taken not to expose them to a high temperature in drying. The following are their formulas:—

PALE ROSE-COLOURED STARS.

No. 4.

Nitrate of strontia . . .	8 parts.
Chlorate of potash . . .	4 „
Sulphur	3 „
Sulphuret of antimony . . .	2 „

Take especial care that the nitrate of strontia used in this formula be very dry.

21. PALE-GREEN STARS.

PALE-GREEN STARS.

No. 5.

Nitrate of baryta	16 parts.
Chlorate of potash . . .	8 „
Sulphur	6 „
Antimony	3 „

The compositions made from both these formulas give a pale colour when seen close; but when falling from a rocket, and viewed at a distance, produce a very charming effect, particularly when contrasted one against the other. They must be moistened with the solution of shellac.

GOLDEN-YELLOW STARS.

22. The next colour that we will deal with is the yellow. The composition for this colour is a very satisfactory one, on account of its having no tendency to deterioration from damp. There are many formulas used for this colour directing the use of the nitrate of soda. This salt is, if anything, more difficult to keep dry than the nitrate of strontia. I therefore have abandoned it for another preparation, which I believe to be *as effective* and thoroughly permanent. I recommend the following for

GOLDEN-YELLOW STARS.

No. 6.

Chlorate of potash . . .	20 parts.
Nitrate of baryta	30 „
Oxalate of soda	15 „
Sulphur	8 „
Shellac	4 „

If it be thought advisable to give the stars made from this formula a tailed appearance, add one part of fine charcoal. The composition is to be moistened with the shellac solution. The stars form a beautiful contrast with those of an intense blue.

BLUE STARS.

23. And now comes the last, and, in my opinion, the most beautiful colour of all. This is the blue. It has generally been considered a very dangerous colour, but the following formulas I have always found thoroughly safe :—

BLUE STARS.

No. 7.

Chlorate of potash	8 parts.
Sulphide of copper	6 „
Chertier's copper	5 „
Sulphur	4 „

Or,

No. 8.

Chlorate of potash	12 „
Chertier's copper	6 „
Sulphur	4 „
Calomel	1 part.

These formulas give a rather pale but very brilliant blue. The compositions have the advantage of being very readily ignited.

PURPLE STARS.

24. If a deeper blue is required, use the following, which I shall dignify by the name of

PURPLE STARS.

No. 9.

Chlorate of potash	16 parts.
Chertier's copper	12 „
Calomel	8 „
Stearine	2 „
Sulphur	2 „
Shellac	1 part.

This gives the most intense blue that I have seen used in pyrotechny, and, with crimson or yellow stars, forms a truly magnificent contrast.

Chertier's copper is a preparation discovered by a Frenchman of that name, and particularly adapted to the requirements of the pyrotechnist. It is made as follows:—Take any quantity of common sulphate of copper (blue vitriol) and dissolve it in as little water as possible; then take an *equal* quantity by weight of chlorate of potash and dissolve it also in as little water as will hold it in solution. Mix these two solutions, and boil them *gently* over a clear fire until the moisture is nearly evaporated; then dry the green precipitate that remains *by a gentle heat*. *When dry* treat it with strong liquor ammoniæ till it changes to a *deep blue* colour; then let it dry very gradually in a warm place. If this operation be properly performed you will have a fine, very light blue powder, which is in reality a *chlorate of potash with copper and ammonia*. This is what I designate as Chertier's copper. Messrs. Bolton and Co. will no doubt prepare it for you if you please.

The stearine employed in the above composition must be in fine powder. It is easily reduced to this state by being treated in the same way as camphor or spermaceti. If a few drops of spirits of wine are used with it, it can be powdered in a mortar.

Compositions Nos. 7, 8, and 9, must be moistened, NOT *with the solution of shellac, but with the gum-water* which have recommended to be used in making up the *brilliant* stars. Care, however, should be taken that for this purpose the gum-water has not become acid by long standing. A very little of the fluid will make the composition bind well, and will enable you to form from it stars of great tenacity and hardness.

I think now that want of variety is a thing that you can hardly complain of; but I must beg you to bear in mind the following particulars:—

The stars of which I have at present spoken are only *for rocket purposes;* they are not to be used for Roman candles. Another plan is adopted with reference to these, and their preparation will be described in its proper place.

When these rocket-stars are to be used some of the powder recommended before must be strewed among them; you can make that mixture weaker if you please, using one proportion of fine charcoal to *five* or even *four* of meal-powder.

The projecting ends of quick-match render these stars much more certain of ignition than the ordinary cubic stars.

It is advisable not to prepare your coloured stars until you are ready to use them, because, unless protected from damp in the most careful manner, they will lose some of their beauty, and you will thereby not be making the most of them. They may appear to you expensive things to prepare, but you must bear in mind that *two or three rockets containing them* are quite sufficient for any one exhibition such as I suppose you will be likely to give.

Remember that the red, green, and blue or purple stars may be used *mixed* with a very beautiful effect. The purple and golden, or purple and crimson, or rose, will also form excellent contrasts.

GOLDEN RAINS.

25. One species of rocket decoration, the manufacture of which I proposed to describe, remains yet to be considered. It is called *Golden Rain,* and with the details of its preparation we will conclude our subject of rocket-making.

Golden rains are made in the following manner:—Procure a piece of brass rod (I always prefer brass for formers, because it is not liable to rust, as is iron or steel), the diameter of which is 3-16ths of an inch, or rather less. The length of the

former may be from 6 to 8 inches. You will now require some thin brown or cartridge paper, of which to make your cases. Cut this paper into short strips, about 2 inches wide, and long enough, when wrapped round the former, to make a case whose external diameter should be a quarter of an inch, or rather more. The former should have a cup-shaped hollow cut in one of its ends, into which the paper may be turned, to form a closed end to your little cases. Paste your strips of cartridge paper all over, and also rub some paste on the former. Now, having turned back one end of your strips—(figs. 32 and 33)—roll it round the former, beginning in the manner here sketched, so that, instead of rolling a single edge of paper round the former, you are rolling a double one. The advantages of this plan for making cases will be more easy for you to see than for me to describe. I may state, however, that you insure, by adopting it, a very close and even fit of the case to the former; you secure the inner edge of the paper from coming unfastened, and you are much more certain that your strips will roll up straightly. This plan may be adopted, if you please, for all cases. I think it is, on the whole, the safest and best. The paste which you rubbed on the former will enable you to draw it out from the case without tearing or injury. But before romoving the former entirely, draw it out only so far as to leave its cupped end a quarter of an inch inside one of the ends of your case—so far, in fact, that a

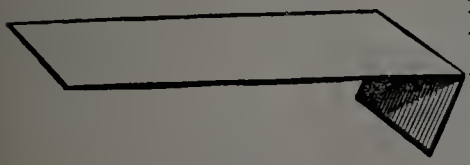


Fig. 32.

Fig. 33.

quarter of an inch of your case remains unoccupied by the former. Now pinch in the paper that projects beyond the former, and drive it down with a tap upon your pasting slab, so that the twisted end is pressed into the cup of the former. By this means you will have a neat and secure end to your cases, which may be dipped afterwards into warm size or glue. If a little red lead be mixed with this size, it will solidify much more rapidly. This dipping the ends of the cases into size should not be done until they are dry from the paste.

Now we come to the filling of these little cases; and for this purpose you will require a simple apparatus, known among pyrotechnists as "the funnel and wire." The funnel is usually made of tin, and has at its mouth a short tube, about a quarter of an inch long, the exterior diameter of which is equal to the exterior diameter of your brass former, so that it will exactly fit into the mouth of your golden-rain cases. The wire should be of steel, about 1-10th of an inch in diameter, and at least 6 inches long. For convenience in working, it should have a small wooden handle. The handles sold in the tool-shops for engravers' tools will answer very well. This is the whole of the apparatus required for making golden rains.

The composition employed for filling the cases is the following :—

GOLDEN RAINS.

Meal powder	6 parts.
Nitre	1 part.
Fine charcoal	2 parts.

Or,

Meal-powder	8 „
Fine charcoal	3 „

Let these ingredients be very intimately mixed. When the composition is ready for use, place the tubular mouth of the funnel in the mouth of one of your little cases; and then put the wire, through the neck of the funnel, down to the bottom of the case. Next, half fill the funnel with one of the above compositions. Now, steadying the case with one hand, raise the wire a little by its handle, and drive it down again. Continue to repeat this operation, giving the wire a succession of short, rapid strokes. You may give about fifteen strokes in five seconds. Each time the wire is raised, a small quantity of the composition falls round it into the case, and the descent of the wire has the effect of driving the composition firmly and compactly into its place. When the case is charged, the funnel must be removed, and the space that was occupied by its nozzle filled with gunpowder paste—gunpowder, that is, or meal-powder moistened with gum-water. This will prevent the composition from being shaken out of the cases, and at the same time forms the best method of priming them. Take care that this paste is pressed well into the mouth of the cases, and fills them.

PORTFIRES.

26. The "funnel and wire" operation is one to which the pyrotechnist has recourse for many purposes, one of which I may as well mention here, as it may fairly be said to come under the head of rocket-manufacture—I mean the preparation of *portfires*.

The portfires, used for firing rockets and fireworks, are generally made in the following manner:—The former for this purpose should be of brass, and not less than a quarter of an inch in diameter, and the wire for filling them not less than one eighth of an inch. Portfire cases are usually made very thin, three rounds of such paper as that on which the

Times is printed being quite sufficient. The cases are prepared in precisely the same manner as that described for golden rains, and are also primed in the same way. The following is the composition which I use for

PORTFIRES.

Nitre	6 parts
Sulphur	2 ,,
Meal-powder	1 part.

Portfires may be made of almost any size, according to the purpose for which they are intended. You will find three-eighths of an inch quite large enough for the inner diameter of any that you are likely to require. If they are to be used for firing exhibitions, you will find that 8 to 12 inches will be a convenient length. The funnel and wire apparatus is so cheaply made that you will be able to provide yourself with two or three sets of these tools, of different sizes, so as to answer any purpose.

We are thus brought to the conclusion of the subject of rockets and their accessories. I trust that I have made my method of operation sufficiently intelligible and plain. The main difficulty that meets any one who attempts to describe a delicate and particular system of working lies in the fact that when one is thoroughly conversant with his subject, particularly in all its minutiæ, he is very liable to overlook, or to treat as unimportant in his directions, some point because it appears trifling to him, and is never likely to be forgotten in *his* practice, the involuntary omission of which, however, may be a frequent cause of failure in the hands of others. I have tried throughout to evade any possibility of misunderstanding; and if I have been too diffuse, it has been solely from the desire to avoid that which has certainly been the fault of almost all the treatises on pyrotechny that

I have seen, viz., indistinctness arising from insufficiency of detail.

Our next subject shall be that of

ROMAN CANDLES.

27. Fireworks of this species are exceedingly beautiful and effective, especially when made with coloured stars, and fired in numbers. Their manufacture is somewhat difficult, but the difficulty is one well worth overcoming. I made a considerable series of experiments before I produced a Roman candle that answered my expectations. At last, however, I hit upon a plan which has never since failed in my hands, and I think that, if I can succeed in making my meaning understood, and you will undertake to follow my directions closely, you will find my plan a good one.

There are several conditions upon which success depends, and which it will be as well to enumerate. A poor Roman candle is not worth making. If you wish to produce one that will satisfy you, remember—

1st.—That you must have a composition to burn in the intervals between the stars, which will produce as good an effect when the Roman candle is almost spent as when first lighted—in fact, which will throw a jet of fire uniformly good throughout.

2nd.—That your stars must be hard enough to resist the pressure of the drift with which you consolidate the composition.

3rd.—That the stars must be of tolerably rapid combustion, otherwise they will not be ignited before they are blown into the air.

4th.—That the charges of powder for blowing the stars must be regulated to a great nicety. If too small, they will not throw them high enough ; if too large, they may burst

the case, or spoil the intended effect of the stars, or so disturb the composition below them that three or four of the stars will be fired in rapid succession, or almost instantaneously.

Now, the first thing to be considered is the size of which Roman candles are to be made. I make them of *one* size only, for I have found that it is much more convenient to have but one size of stars to prepare, and one size of cases to roll, and one scale of powder-charge to remember, than to run the risk of confusion by having to think of various sizes. Besides, all the effect that these pieces are capable of can be produced by my one size. This size is *that called the 2 oz. Roman candle*. The former for the cases must be five-eighths of an inch in diameter, and should be 18 inches long.

These fireworks require rather a large amount of paper and imperial board for the manufacture of their cases. A good stout case may be made as follows:—Cut your sheets of 70-lb. brown paper into halves, and your sheets of imperial board into six equal pieces. One of these pieces, with one half-sheet of 70 lb. paper, will make one case. Paste your pieces of imperial board *all over*, as well as the sheets of paper. Rub some paste on your former, and proceed to roll a piece of the pasted board tightly and smoothly round the former till all but about two inches of it is rolled. Then take the pasted half-sheet of brown paper, and roll this upon the imperial board in the manner described for making golden rain cases. The method there given is of especial value when the cases that you are making are of considerable length, because it enables you to roll the paper and board very straightly, which cannot be done so easily by any other means that I know of. The cases thus made will be pasted throughout and can be easily removed from off the former. They will be about 14 inches long, which is a very good size. You can, of course, make them shorter for experiments, but

you will find the above size not too large for exhibition purposes. I do not think it will do to make the cases very much thinner than I have directed, but a few experiments will decide what length or thickness of case succeeds best in your hands. I have given you my size, which I have no wish to alter.

Now the next thing to be done is to prepare the stars. These are made in a tubular mould, the exact size of which I have sketched in the page of illustrations, Fig. 37. But before giving you directions for making these stars, I may as well furnish you with a few formulas for their composition.

WHITE ROMAN-CANDLE STARS.

28. The brilliant stars may be made of the same composition as that given you for rocket stars of that kind. If, however, you require a *more white* star, use the following:—

WHITE ROMAN CANDLE STARS.

Composition No. 1.

Nitre.	48 parts
Sulphur	10 „
Regulus of antimony . . .	8 „
Realgar	6 „
Red lead	4 „
Shellac	1 part.

This formula gives a much purer white than the formula for ordinary brilliant stars, which are always bluish in tint. Composition No. 1 must be moistened with the solution of shellac recommended for rocket stars.

YELLOW ROMAN-CANDLE STARS.

29. Yellow Roman-candle stars may be made from the same formula as that given for yellow rocket stars.

GREEK ROMAN-CANDLE STARS.

30. Greek Roman candle stars may be made from the formulas given for rocket stars; but there is also another formula, which produces a rather deeper tint, but is hardly rapid enough in combustion for rocket stars. It is the following:—

GREEN ROMAN-CANDLE STARS.

Composition No. 2.

Nitrate of baryta	40 parts.
Chlorate of potash. . . .	20 „
Calomel	12 „
Sulphur	12 „
Shellac (fine)	4 „
Charcoal (fine)	1 part.

This composition must be moistened with the solution of shellac. It will produce a most lovely colour, *if the baryta be pure.*

CRIMSON, ROSE, BLUE, AND PURPLE ROMAN-CANDLE STARS.

31. The formulas for crimson, rose, blue, and purple Roman-candle stars are the same as given for rocket stars, and must be moistened with the liquid directed in my last paper as proper for each one.

You have now formulas for making brilliant, white, golden, green, crimson, rose, blue, and purple stars.

ROMAN-CANDLE STARS (To Make).

32. In order to make the stars, moisten the compositions *very slightly.* The mould in which these stars are shaped is a brass tube of a size proportioned to the size of the Roman-candle case, and is generally about one-sixteenth of an inch smaller in its inner diameter than the case. The drift with

which the composition is pressed into the tube is made of box-wood or metal, and fits easily into the tubular mould. At one of its ends there is a wire point. Place the end having the point in the mould as far as it will go. You will find a space left at the end of the mould unoccupied by the drift. Press this empty end of the tube into the slightly-moistened composition until it is filled by it, so that the drift, being driven down upon the composition, will compress it into a firm cylindrical mass, into the centre of which the wire point projects. Figures 35, 37, and 39, represent the mould, drift, and finished star. When the star is thus formed in the mould the drift must be reversed, and its long plain end inserted, and the star pushed out. The object of making the star hollow is that it may dry and harden perfectly in its centre. If heat is employed to dry the stars, they have a tendency to harden outside rapidly, and thereby an impervious coating is formed, through which the inner moisture cannot evaporate. This difficulty is obviated by leaving a hole in the centre of the star, and this hole is made of use for another important purpose—namely, *the priming* of the star.

My plan for insuring the ignition of the stars is, as far as I know, peculiar to myself, and I have the satisfaction of knowing that it has never failed me. Some pyrotechnists recommend the smearing of the star with a very combustible paste; this plan, however, must to some extent injure the colour of the star. I simply place a little piece of quick-match into the hole in the star, and allow it to project about a quarter of an inch above. By this means even slowly-combustible stars are ignited, and almost every chance of failure is avoided.

This priming, however, should not be done until the stars are to be put into the cases—at all events, till they are perfectly dry. Their drying may be effected naturally out-of-doors in the summer, when a very few hours' exposure in the

sun will render them thoroughly hard and fit for use. In the winter time, however, artificial heat should be used. I always find that the more rapidly, *up to a certain point*, these stars are hardened, the better they keep. Nothing, however, will be gained by hurrying them through this process, except a danger of their exploding. Place them carefully, and not touching one another, in a tin box having a lid, and let this box remain at such a distance before a fire that it can become thoroughly warm, *not hot*, till the stars are thought hard enough to be put away. They should be kept, when dry, in closely-stoppered bottles in a dry place. Each star will weigh, at least, thirty grains.

COMPOSITION FOR ROMAN CANDLES.

33. I must now suppose your stars and cases to be ready for use; and, therefore, the next thing to be considered will be the composition which is to form the intervals between the stars in the cases. For this purpose I give you three formulas.

COMPOSITION FOR ROMAN CANDLES.

No. 1.

Nitre	18 parts.
Sulphur	6 ,,
Charcoal (fine)	7 ,,
Meal-powder	4 ,,

This composition is one which answers very well. I think, however, that the following is better, being rather more rapid in its combustion, and thus capable of producing a more decided effect when burning at the lower end of the case:—

No. 2.

Nitre	16 parts.
Meal-powder.	8 ,,
Charcoal (fine)	6 ,,
Sulphur	6 ,,

This is the composition which I generally employ. Both of these formulas give rather a dusty mixture, and can be used with much greater cleanliness and comfort if slightly moistened. Only so much spirits of wine or gin must be used as will render them less dusty, and not wet. The following composition is very useful, but produces rather a jet of flame with sparks than a rich sparkling fountain :—

No. 3.

Nitre	16 parts.
Meal-powder.	11 ,,
Sulphur	6 ,,
Antimony	4 ,,

This composition is of a more heavy and less dusty nature, but can also be slightly moistened, if you find it more convenient to use it when thus treated. Take care that in each case the ingredients are well mixed.

ROMAN-CANDLE CASES (To Fill).

34. Having selected one of the above compositions, you will now be ready to fill your cases. For this part of your work you will require a small turned block of wood, like that drawn in the page of illustrations (fig. 40). This block with its projecting piece is called a "settle." One end of your Roman-candle case is pressed over the upper part of this settle, which is made of a size to fit into it tightly. By this means the case will be supported while it is being filled. The first thing to be done is to close up one end of the case. This is done by ramming in a small quantity of dry potter's clay, such as you used for rockets ; this being driven down over the top of the settle will form a very hard, firm end.

CHARGES FOR ROMAN CANDLES.

35. We now have to enter upon the most difficult part of the manufacture of Roman candles. This is the regulation of the charges of powder which are to blow the stars into the air. These are so small, and necessarily so, that unless their quantity be very accurately measured you are very likely to spoil the performance of the whole. The following table will give you *an approximate* idea of the quantity that each charge should contain; but so much depends upon the *quality* of the gunpowder which you employ, that it is impossible to give you anything more than an approximation:—

For the 1st star	. . .	3 grains.
„ 2nd „	. . .	4 „
„ 3rd „	. . .	4 „
„ 4th „	. . .	5 „
„ 5th „	. . .	5 „
„ 6th „	. . .	6 „
„ 7th „	. . .	6 „
„ 8th „	. . .	7 „
„ 9th „	. . .	8 „
„ 10th „	. . .	30 „

Gunpowder exerts more or less force in its combustion in proportion as it meets with more or less resistance. It is in accordance with this principle that those charges of gunpowder which are at or near the lower end of the Roman-candle case, are obliged to be much smaller than those placed nearer its mouth. If it were not so, and all the charges were alike, when the combustion reached a certain point the case would be burst. You must modify the quantities given in the above table until you produce the greatest and best effect with the

greatest economy of power. I think that the five first charges will not require to be altered much. I have given charges for *ten* stars. You need not, of course, put so many into the case; but you should not put in less than *eight.* All must depend in this matter upon the quantity of composition which you like to use in the intervals between the stars. *Only be sure to keep the two last charges of gunpowder always the same, and do not place the two last stars too near the mouth of the case.* The reason why these rules must be observed is that the force of the charges of gunpowder which lie near the mouth of the case is so soon spent, that if the stars are too near the mouth of the Roman candle they will do little more than fall out of the case, instead of being blown to their proper height. The first star means, not that one which is fired first from the Roman candle, *but that which is first put into it.*

Your best plan for measuring the charges of powder is to have some small scoops or ladles made of very thin sheet-brass, of the same shape as that used in filling rockets, and capable of holding exactly the right charge of powder for each star. This is the only plan that I am aware of for insuring with any accuracy the various quantities.

Now, having your stars primed, as directed above, with quick-match, your clay rammed firmly into the lower end of the case, and your composition ready moistened for use, you must cut some *thin* touch-paper into squares of an inch in size. Next you must be provided with a round stick with a flat end, which will pass easily into the case from one end to the other, not shorter than *eighteen inches.* Your materials and apparatus are now complete.

First put into the case the first charge of gunpowder, and take care that this finds its way to the bottom of the case; drop in next the first star, *with its priming upwards.* Take

care also that the star lies directly upon the charge of powder. Now, by means of another brass scoop made to hold the proper quantity of composition, put into the case half the quantity that is to be rammed between the first and second stars. You must then press this into its place by means of your ramming-stick. This can be done with the hand, without any mallet. The weight of a mallet would break the star beneath. Remember always to ram in the composition which is to form the interval between the stars *in two quantities.* If you attempt to ram it all in at once it will not be sufficiently consolidated, and its combustion will be too rapid. The quantity of composition must depend entirely upon your own taste. I generally put in as much, in two quantities, as will rise about an inch in height in the case; it will not do to put in less.

Then upon the top of this composition put one of the square pieces of thin touch-paper. This may be rammed down in the same manner in which a gun-wadding is driven upon the top of the charge. The object of this little piece of touch-paper is to prevent the charge of powder which is above it from disturbing in its explosion the composition which is below it. This I have always found it most effectually does, and allows, moreover, of the use of a rather stronger charge of powder, than could be employed without it. Having put this in flatly, measure out your second charge of powder, and put upon the top of it your second star, then another half-charge of composition, then the remaining half-charge, then another piece of thin touch-paper, and so on till the case is filled. *The last charge of powder should not be less than two inches below the mouth of the case.* The Roman candles should always begin with composition in their burning.

ARRANGEMENT OF STARS.

36. With regard to the arrangement of the stars, I generally vary the colours as much as possible in each Roman candle. If these pieces are to be fired singly, it matters little what the order of the colours is; but if they are to be fired in numbers, it will be necessary to arrange them so that they do not throw up the same colours at the same time. The plan that I adopt to prevent this is the following:—I make out a list of the coloured stars that I have ready to use, arranging them, for instance, in the following order:—brilliant, green, yellow, blue, red, white, purple, rose. The *first* Roman candle may be filled with its stars in this order. In the second I should begin with the green, in the third with the yellow, and so on, till all that are to be fired at once are completed.

PREPARATION OF TOUCH-PAPER.

37. I have spoken about touch-paper, but I do not think that I have yet described its preparation. This is very simple. Obtain some thin blue paper—not so thin as tissue-paper, but thinner than the ordinary blue paper used by shopkeepers—brush or sponge this over with a weak solution of nitre. If this solution is made too strong, the nitre will recrystallise as the water evaporates in drying, and this should not be the case.

QUICK-MATCH.

38. Quick-match, of a quality good enough to answer for priming to the Roman-candle stars, may be made simply as follows:—Make a thick paste of gunpowder and hot water with a small quantity of gum in it. Take about four strands

of cotton, such as is sold in balls and used for making the wicks of lamps, steep this in the solution of nitre used above for making touch-paper, and then wring it as dry as possible; then rub it well in the gunpowder paste till it is thoroughly covered with it. One end of the cotton may then be passed through a small funnel, whose mouth is not more than an eighth of an inch in width. By this means, if the whole length of the cotton is drawn through it, the superfluous paste will be removed, and the match will be of a nice round form. Hang it out of doors on a dry day, and when it is nearly dry coil it upon a tray or paper, and dust it over with meal-powder. In winter it will not be sufficiently dry for use under a week. When thoroughly dry it should be stiff and hard, and the less it is bent or doubled the better.

If you wish to use this match for connecting the mouths of different fireworks, or "clothing" them, as it is termed, you must make some long paper tubes round a wire former which has a diameter of not less than three-sixteenths of an inch. These pipes are threaded on the match, and have a piece cut away at their side wherever they are inserted into the mouth of a case, in order that the match may be laid bare and convey its fire to the priming of the cases.

I have given you these short hints for the preparation of a quick-match. I cannot, however, recommend your acting upon them, as the manufacture of this useful article involves a great deal of very dirty work. Unfortunately, quick-match is rather expensive to buy, while it may be made at a very trifling cost. It is a most indispensable accessory, and if you dare face the dirty work, you will find your courage will well repay you. You may prepare it any way that you please, remembering that all that is necessary is to coat the cotton well with a highly-combustible compound, and one which will dry thoroughly.

Your Roman candles, when charged, should be finished with touch-paper; or with ordinary paper, to receive the quick-match, if they are intended to be fired simultaneously in numbers.

I trust that the above directions will enable you to succeed in the manufacture of a species of firework without which no exhibition can be complete, and with which so many and beautiful effects may be produced.

In case you should prefer to buy your chemicals and various ingredients of an operative chemist, I beg to refer you to Messrs. Bolton & Co., 146, Holborn-bars, London, in whose preparations I have great confidence, and who will undertake to supply you with all the articles required in pyrotechny at the prices in the subjoined list. You will perceive that it is much more economical to purchase them *by the pound* whenever they are required in such quantities. Many of the things, however, you will need to use only sparingly, and these, therefore, may be bought by the ounce. I think the following list will be found to contain nearly all the preparations that you will require; there may be a few things omitted, such, for instance, as red-lead (used in the composition for white Roman-candle stars), but this can be procured of any country chemist or painter :—

	Per lb.		Per oz.	
	s.	*d.*	*s.*	*d.*
Nitre in powder. . . .	0	8 ...	—	
Meal-powder . . .	1	0 ...	—	
Sulphur	0	4 ...	—	
Charcoal . . 4*d.* to	0	8 ...	—	
Calomel	5	0 ...	0	4
Nitrate of strontia . .	1	0 ...	0	1
do. do. anhydrous .	2	0 ...	0	2

	Per lb		Per oz.	
	s.	*d.*	*s.*	*d.*
Nitrate of baryta . .	1	0 ...	0	1
Do. do. anhydrous .	2	0 ...	0	2
Chertier's copper . . .	4	6 ...	0	4
Oxalate of soda . . .	3	0 ...	0	3
Shellac in powder . .	3	0 ...	0	3
Sulphide of copper fused .	2	6 ...	0	2
Realgar	2	0 ...	0	2
Carbonate of strontia . .	2	0 ...	0	2
Stearine	2	0 ...	0	2
Regulus of antimony . .	1	9 ...	0	2
Bright steel-filings . .	1	0 ...	0	1
Cast-iron borings . .	0	6 ...	—	
Powdered glass . . .	1	0 ...	0	1

I have now only to give you a brief description of the wood-cuts. Fig. 34 represents the funnel into which golden-rain composition is placed; Fig. 35 the drift with which it is rammed; Fig. 36 the case which is to contain it; Fig. 37 represents the tubular Roman-candle star mould; Fig. 38 the drift with which the stars are rammed; Fig. 39 the finished star with its quick-match priming; Fig. 40 represents the settle with its upper part on which the Roman-candle case is to be supported.

The next portion of our subject with which we have to deal is that which comes under the head of

GERBES AND JETS OF BRILLIANT, CHINESE, AND COMMON FIRES.

CHINESE AND BRILLIANT FIRES.

39. These are certainly among the most beautiful and effective pieces to be met with in the whole range of pyrotechny.

They should find a place in every exhibition, and, if only prepared properly, according to the directions which I am now about to give, will be sure to prove one of the most striking features in your display.

They have one great advantage—that there is no limit to the modes of combination or arrangement in which these pieces may be effectively employed. By means of them you can make any such things as the following:—Fountains of any size or design, cascades, brilliant suns, either fixed or revolving; bouquets of Chinese fire, Prince of Wales's feathers, trees of silver flowers, and a thousand other devices which will readily occur to you.

But, like many other things which are possessed of highly useful or ornamental qualities, they have a corresponding disadvantage. Their compositions, to produce the desired effect, must be made *as shortly as possible before you intend* to fire them; for the ingredients upon which they rely for their beauty are *filings of steel for brilliant fires*, and *borings of iron for Chinese fires*, and unless these filings and borings be entirely free from rust at the time when they are fired, the effect produced will be insignificant as compared with what it should be. And it must be borne in mind that both iron and steel become very soon and very easily corroded when mixed with any composition into which nitre and sulphur enter. I have known cases filled with brilliant or Chinese fire remain good for a week in winter; but I do not suppose that even then their performance was at all what it would have been if they had been prepared for a few hours only.

Many attempts have been made to secure these metallic ingredients from corrosion. Some have stirred the filings in a varnish made of resin and spirit; others have shaken them about in powdered black-lead, and so coated them with this substance. But a coating of any kind is tolerably certain

either to rob the spark, which each particle of metal should produce, of its brilliancy, or to render the composition during combustion very smoky, and so impair the intended effect.

By far the most successful preparation of steel and iron that I have noticed is the following :—A weak solution of asphalt in naptha is made, and the filings or borings are stirred about in this. When it is thought that they are thoroughly covered with it, the solution is poured off, and the filings spread out upon a paper to dry. This plan will protect them from rust for a little time longer than they would otherwise remain uncorroded. But still the best plan is to prepare the compositions as short a time as possible before they are to be fired.

The size that I recommend for cases which are intended to contain Chinese fire is that called the *two ounce* case. To make them, the same former may be used as was employed in the manufacture of Roman-candle cases already described.

The paper and imperial board may be cut of the following sizes. Open your sheet of paper, *of the 70-lb. thickness,* to its full size, and divide it into three pieces, as shown in the following wood-cut, Fig. 41 :—

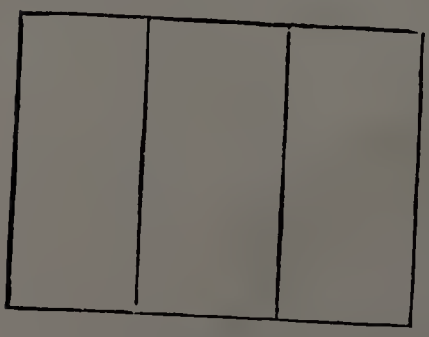


Fig 41.

Then open your sheet of imperial board to its full size, and divide it thus into nine equal pieces, Fig. 42.

So that by these arrangements one sheet of imperial board and three sheets of 70-lb. brown paper will furnish you with material for *nine* cases, each of which will be about nine and a-half inches in length.

My plan for rolling the cases is that which I have described in paragraph 25, but which may perhaps, be rendered slightly more intelligible by the accompanying sketch. Having pasted one of my strips of paper and one piece of board all over on one side, and having brushed some paste over my metal former, I lay the former across the strip of paper about one-third of its whole length from the end nearest to me. I then double the one-third of the strip, pasted side downwards, over the former, on to the remaining two-thirds, Fig, 43, taking care that the edges of the one are even and parallel with the edges of the other. Then having made a crease in the upper fold just in front of the former, I put into this crease the pasted piece of imperial board, and roll up the whole together. It is necessary, however, *to paste the upper side* of the fold of paper which you have made round the former. This I have always found a very quick, and easy, and perfect method of preparing cases of any kind. I trust that I have rendered my meaning plain, as I shall have occasion to refer frequently to this operation. The rolling-board must, of course be used.

Fig 42.

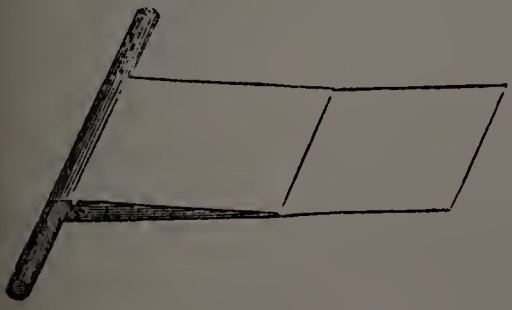


Fig. 43.

The cases when made are to be choked, *while wet*, precisely in the same manner as described for rocket cases, only it must be remembered that their aperture may be almost choked up,

because when it has been reopened by the point over which they are loaded, *it must not be more than one-third of the interior diameter of the case in size.*

Having described the manufacture of the cases, I now proceed to give the formulas for the composition of

CHINESE FIRE.

40. There are two sorts of this fire which are known by the names *red* and *white.* The red is that which contains charcoal, and *therefore has some red sparks intermixed with those produced by the iron;* the white is that *the sparks of which are produced by the iron only.* It is my intention to give several formulas for this fire, in order that my readers may select for themselves, and use that which they find most successful.

No. 1.

Meal-powder	16 parts
Nitre	16 „
Sulphur	4 „
Charcoal (No. 2)	4 „
Iron borings	14 „

Or the following is quicker in combustion :—

No. 2.

Meal-powder	16 „
Sulphur	3 „
Charcoal	3 „
Iron borings	7 „

Or,

No. 3.

Meal powder	8 „
Nitre	16 „

Sulphur	3 parts
Charcoal	3 „
Iron borings	8 „

Or,

No 4.

Meal-powder	16 „
Nitre	8 „
Sulphur	4 „
Charcoal	3 „
Iron borings.	7 „

The compositions given above produce what is termed *Red Chinese Fire*, since they all contain charcoal. I have numbered the charcoal, because Mr. Bolton, 146, Holborn-bars, supplies three different degrees of fineness, the *second* of which is proper for this purpose.

The following formulas will produce what is called White Chinese Fire :—

No. 5.

Meal-powder	16 parts.
Nitre	6 „
Sulphur	3 „
Iron borings	10 „

Or,

No. 6.

Meal-powder	16 „
Nitre	4 „
Sulphur	2 „
Iron borings	6 „

Or,

No. 7.

Meal-powder	16 „
Iron borings	5 „

It is an understood rule among pyrotechnists that the smaller the diameter of the case employed the quicker must

be the composition with which it is filled; or, in other words, a quick composition which answers well in a case of small diameter will burn too rapidly, or explode, in a case of larger dimensions. My readers must therefore first determine the size of the case that they intend to use. It will not be well to adopt any size of case smaller than the *two ounce* for Chinese fire. If, however, the $\frac{1}{4}$ lb. size be chosen, I should recommend the compositions No. 1, No. 3, or No. 5. Nos. 2, 4, 6, 7 will answer very well in a case of the 2-oz. size.

But if it be thought advisable to have recourse to a case of the $\frac{1}{2}$ lb. size, a still weaker composition will be required, in which case the following formulas may be used :—

No. 8.

Nitre	16 parts.
Sulphur	3 „
Charcoal	4 „
Iron borings	7 „

Or,

No. 9.

Nitre	20 „
Sulphur	4 „
Charcoal	4 „
Iron borings	12 „

For general purposes, cases of the 2 oz. size will be found quite large enough, particularly when used in combination, and not fired singly.

The most effective of all the compositions that I have given is No. 7, which consists of meal-powder and iron-borings only, but it is very rapid and fierce in its combustion, and will burst the cases into which it is put unless great care be taken in the ramming. A very little of the composition must be rammed at a time, in order to insure a thoroughly equal

and solid compression throughout the case. If properly managed a two-ounce case filled with this composition will throw a very brilliant jet of large flowers of fire from eight to ten feet in height.

I have sometimes thought that the moistening of composition No. 7 with a little turpentine, so that it becomes less dusty, has the effect of preserving the iron or steel from rust to some extent. At all events, it greatly facilitates the uniform mixing of the ingredients. It must, however, be especially borne in mind that *neither spirits of wine nor gin must be used to moisten any composition containing iron or steel.*

The iron borings which Mr. Darby will supply are very effective for the preparation of Chinese fire.

You should take care that the other ingredients are thoroughly mixed before you add the iron borings, and then that the iron be equally distributed throughout the mixture.

The next operation is the filling of the cases. For this you will require some tools not before mentioned, which I will now proceed to describe.

You should get Mr. Newman to make you three solid drifts which will pass very easily into your 2-oz. cases. The first of these should be about *nine inches long*, the second about five inches long, and the third two inches long. These tools will always be found convenient for many purposes in pyrotechny, and not only for the filling of Chinese fire cases. The two longest of these drifts should be about *nine-sixteenths of an inch in diameter;* the third may be nearly five-eights of an inch.

Your mallet should be, in the measurement of its head, five inches long and three in diameter. It should be made either of ash or beech.

In the next place you will require a block with a nipple and point, such as is drawn in the page of illustrations, figs. 44, 45 and 46. This may be made of wood, with its point only

of metal; but I much prefer a metal nipple and point. Mr. Newman has made for me a set of nipples and settles in gun-metal, *all of which fit into the same block.* They answer all purposes, and take up very little room; whereas you will find a multiplicity of blocks very inconvenient, if your accommodation is as scanty as mine.

You must, of course, have a scoop of a proper size for filling 2-oz. cases, and this, I think, will complete your tools.

Your case must now be pressed over the point of your nipple, and by this means its aperture will be made of the proper size. You will find it very convenient to have a ring of iron fixed into your block, through which the case must be passed, which will steady it and keep it in a perpendicular position while being filled (fig. 47).

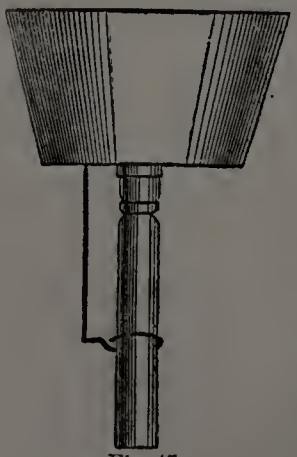


Fig. 47.

And this is in reality more than a matter of convenience, for unless the case be perpendicular while the operation of filling is going on, the blows of the mallet will not have their proper effect, and the composition will not be thoroughly consolidated; or, what is worse, the neck of the case may be wrenched or injured in some manner, and will in all probability give way and burst upon the combustion of the composition.

Now drive in your composition, a ladleful at a time, and, after putting in each ladleful, give the drift twelve blows with the mallet. Fill the cases till there remains a space of *two inches only* unoccupied at the end. Into this end put *a gun-charge and a half* of gunpowder. Then with a bradawl separate one or two of the inner folds of the paper of the case, and turn these down on the top of the powder.

My method of filling in the ends of the cases is the following:—Melt in an earthen pipkin a mixture of two parts of common resin and one of wax. This may be poured into the ends of the cases upon the paper that has been turned down. It will harden in a few minutes, and will be found to insure you a good report from the powder.

It only remains now to prime these cases. This is an operation requiring some care, although it may be performed in a very simple manner. If the point of your nipple is not too long—that is, is only long enough to *reach* the composition *without penetrating it*—all that you need do is to press into the mouth of the case some meal-powder paste; but if a cavity has been left in the composition, this must be filled up before priming, or the case will inevitably burst.

It is an excellent plan to take for your first ladleful, not any of the compositions for Chinese fire, but a ladleful of some slower fire containing no iron borings. You may use a mixture consisting of

Nitre.	6 parts.
Sulphur	1 part.
Charcoal	1 „

The advantage of attending to this piece of advice will be very apparent to you, and I strongly recommend the plan to your notice in the case of *brilliant*, as well as of Chinese, fires.

Fig. 48

Having now described the manufacture of the cases of Chinese fire, I shall proceed to point out to you some of the combinations in which they may be used. The simplest is the ordinary Prince of

Wales Feather, the frame-work of which any blacksmith can make in thin iron rod, having a couple of holes drilled in it, through which screws may be driven to fasten it to your post. I give you two sketches (figs. 48 and 49), the former of which has, in my opinion, rather the advantage. The mouths of the cases must, of course, be connected with quick-match, so that they all take fire simultaneously. By having a framework made of iron it will be liable to no injury from the explosions at the end of the cases. The same framework may be used with three Roman candles, instead of Chinese fire cases, and with excellent effect.

Fig. 49.—Princeof Wales' Feathers.

The next most simple combination is that which is called the Bouquet of Chinese Fire. It should be made with, at least, five cases, and will then be found very effective in its performance. Its framework is of very simple construction, and may be made in a few minutes by any boy. The accompanying sketch (fig. 50), will prevent the necessity of any further explanation.

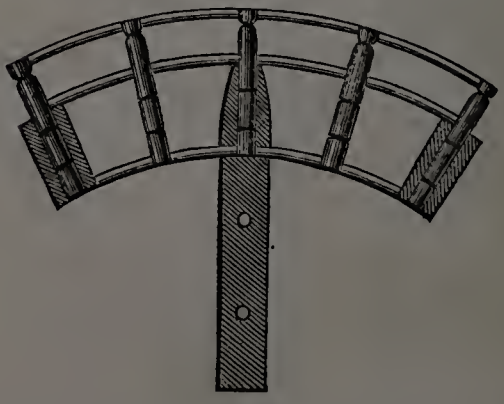


Fig. 50.

A very pretty piece may be made, representing a tree of silver flowers. Procure a straight piece of deal of any length that you require (the length must be determined by the number of cases that you intend to use). This will

answer for the trunk of the tree. To this nail some pieces of lath in the shape given in the adjoining woodcut (fig. 51). On each of these, and at the top of the straight piece, tie a case of Chinese fire, and connect all the mouths of the cases by means of quick-match. When ignited, this piece will present a very beautiful appearance, and may be made a highly satisfactory conclusion to a small exhibition.

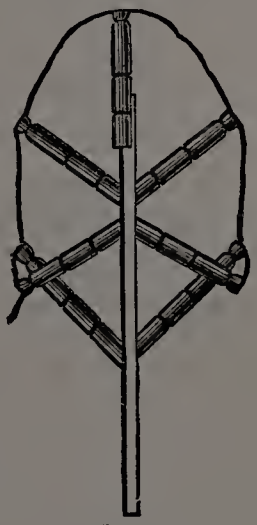


Fig. 51.

It is worthy of remark that all pieces in which Chinese fire is used should be raised to a considerable height from the ground, otherwise they will lose much of their beauty, for the sparks produced by the particles of iron are thrown much farther, and remain visible much longer, on account of their superior size, than those produced by steel, and if they have not a certain distance through which to fall, much of their effect will be thrown away. The post on which I fire nearly all my pieces *stands ten feet out of the ground.* It is made of deal painted with lead-colour, and is about three inches square. It can be taken down or put up at a moment's notice, as it fits into an oak box sunk in the ground, of the same kind as those used in drying grounds. If you have a post of this kind made, see that the part which fits into the box is *not straight*, but slightly tapered. This will allow of a better fit, and enable you to remove it far more easily when required.

There are many combinations which it will not be at all necessary for me to notice here, for the firing of one of these cases of Chinese fire is not only a beautiful thing in itself, but is also very suggestive of different devices under which this valuable preparation may be employed. If any of my

readers should hit upon any unusually good device I shall be glad to hear of it through the publishers of this book; and if my readers, in the course of their experiments, should stumble upon a really good plan for preparing iron borings and steel filings so that they become incorrodible, they will confer a great favour upon the pyrotechnic world by making it known.

Be sure not to forget to first ram into your cases half-a-ladleful of the preparatory fire given above: it will save you many a disappointment. If you prefer a composition a little quicker, add some meal-powder to it.

Having said all that is necessary to make the manufacture of Chinese Fire intelligible, I pass on to consider, in the next place, the subject of Brilliant Fire.

BRILLIANT FIRE.

41.—The points of difference between brilliant and Chinese fires are these:—

1st.—The sparks produced in the combustion of brilliant fire by steel filings are much whiter, but at the same time much smaller and shorter-lived, than those produced by iron borings in Chinese fire.

2nd.—The steel sparks are not thrown to so great a distance, on account of their superior weight and size; but they are much more numerous, and afford a rich tale, or "brush," as it is termed, of glowing scintillations, rather than a gracefully-falling jet or fountain of large sparks. This very fact, however, of their not being thrown so far from the case out of which they are fired renders them capable of producing an effect in combination of which Chinese fire is incapable. The cases, when arranged in the position of the radii of a circle or spokes of a wheel, will throw a *perfectly straight* brush of brilliant fire, which will,

of course, much more closely represent rays of light emanating from a centre than any fire the sparks of which have a tendency to fall.

3rd.—Another point of difference between the composition containing iron borings and that containing steel filings is that the former should never be employed in the construction of pieces which have motion ; for the very motion of the piece, or rather the increased impetus with which the particles of *iron* are thrown out into the cold air, has the effect of cooling them so rapidly that almost all their beauty is lost. But this is not the case with *steel filings:* they seem almost unaffected by the rapid motion of the piece in which they are employed ; and for this reason they possess an advantage which fully makes up for their being so much less showy in their performance than the iron borings.

The cases into which the composition for brilliant fire is rammed need not be so large as those employed for Chinese fire. I employ two sizes—the 1-oz. size for cases that are intended to turn wheels or any revolving pieces, and a smaller size still for those that are to remain perfectly stationary during their combustion.

The fault into which the young pyrotechnist is most likely to fall is that of using a power considerably in advance of his need. In order that you may not do this (for there is always fear of failure when you do), I recommend you *to use no cases for brilliant fire larger than the one-ounce size.* This, you will find, will give you a moving power amply sufficient for any wheels that I suppose you are likely to use, and particularly if you bear in mind the rule, that *increase of power is gained much more safely and much more effectively by an additional number of cases burning at the same time than by any additional force that you can get out of one case.*

The 1-oz. case, as you know by this time, is made round a

former exactly half-an-inch in exterior diameter and 12 inches long. The paper for these cases may be cut precisely in the same manner as directed for Chinese fire-cases. The imperial board should be cut thus (fig. 52), into twelve equal pieces. Take care that the *long* side of the board is divided into *three*, and the *short* into four.

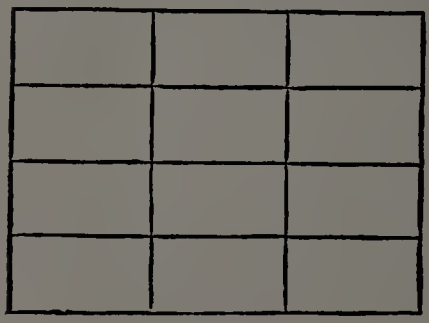


Fig 52.

If, however, you think a shorter case sufficient, cut your sheets of paper into eight equal parts, thus (fig. 53), and your imperial board into sixteen pieces—that is, half the length of the strips of paper; this will give you cases about five and a-half inches in length. Both these divisions of paper and board are for the 1-oz. cases.

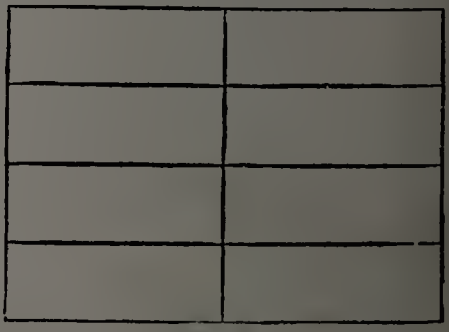


Fig. 53.

I will now speak of the smaller sizes, which are used only in fixed pieces, and which are generally called on that account, for the sake of distinction, *fixed cases*.

The former for these is a metal tube 12 inches long and seven-sixteenths of an inch in exterior diameter. For cases of this size you may either use paper and board cut as directed above for the longer 1-oz. cases, or you may divide each sheet of paper into six strips thus (fig. 54), and each sheet of board into twelve pieces half the length of the strips of paper.

For filling either the 1-oz. or the fixed cases it will be

evident that you must have at least two drifts for each size that will pass *easily* into their respective cases — one one about 9 inches long in its straight part, and the other from 2 to 3 inches in length.

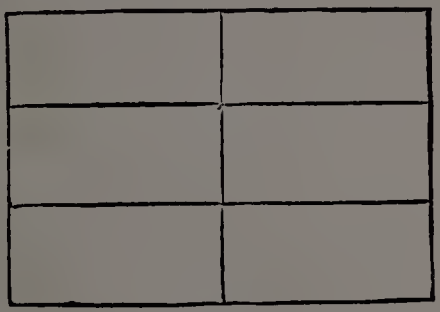


Fig. 54

You must also have a nipple and point over which to ram each different size of case. The exact size of these nipples you will see in the pages of illustrations (figs. 45 and 46).

Use the same mallet and observe the same rules in filling these brilliant fire cases as in filling the cases with Chinese fire.

We are now ready for the compositions. The first given is by far the most beautiful, and most generally used ; but being very rapid in its combustion, it must be very carefully and uniformly compressed in the case. No. 2 is of a much quieter character, and may be found useful for some purposes.

BRILLIANT FIRE.

No. 1.

Meal powder	4 parts.
Bright steel filings . . .	1 part.

Or,

No. 2.

Meal powder	16 parts.
Nitre	8 „
Sulphur	3 „
Fine Charcoal	3 „
Bright steel filings	10 „

Neither of these compositions should on any account be mixed before their preparation is absolutely necessary, for their whole beauty depends upon the brightness of the filings at the time of firing.

COMMON AND SPARKLING FIRES.

42. I will now give a few formulas for common and sparkling fires, which will in all probability be found very useful for jets and fixed pieces.

COMMON AND SPARKLING FIRES.

No. 1.

Meal powder	4 parts.
Charcoal No. 2	1 part.

Or,

No. 2.

Meal powder	16 parts.
Nitre	8 „
Sulphur	4 „
Charcoal No. 2	4 „

Or,

No. 3.

Meal powder	16 „
Very fine glass dust	5 „

Or,

No. 4.

Meal powder	8 „
Very finely powdered porcelain	3 „

These four compositions will be found effective for many purposes, but should not be used in cases under the *one-ounce size*. Their great advantage is that they are not in the least degree impaired by keeping. They are to be rammed into the cases in precisely the same manner as directed for Chinese fire.

BRILLIANT FIRE.—EFFECTIVE COMBINATION.

43. But now to return to *brilliant* fire. I will suppose you to be using some of the first composition given, and to have completed the filling of a few cases. Let us see what we can do with these to put them into effective combination.

Provide a circular disc of hard wood, 6 inches in diameter, and 1 inch thick. This is to form the centre of your piece. Nail to this five spokes of wood at equal distances from one another, and 15 inches long. Nail also to the back of the central disc a strip of wood about 2 feet long, 2 inches wide, and three-quarters of an inch thick (fig. 54). By means of this you can screw the whole piece conveniently to your firing post. On each of the five spokes tie a case of brilliant fire, reported at its end, and connect the mouths of these with quick-match. The effect produced by this piece is very surprising, when we take into account its extreme simplicity. Its beauty may, however, be much enhanced by the addition of a Chinese flyer to its centre; but the manufacture of this auxiliary has not yet been described, and must not be spoken of out of its place.

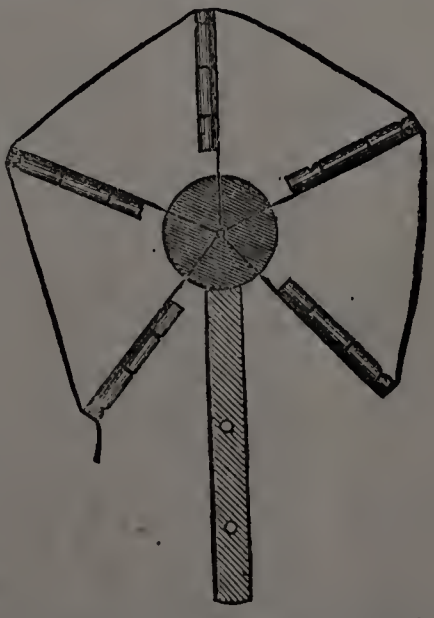


Fig. 54.—Five pointed star in brilliant fire.

A simple large wheel of brilliant fire may be made by fastening two cases to each end of a strip of wood about 30 inches long, the centre of which strip is made thick enough to

turn steadily on an iron spindle. The cases are tied on at an angle so as to throw a large circle of fire. The mouth of the case at one end is connected with that at the other by means of quick-match. When these two cases are consumed they communicate their fire to the two inner ones by a quick-match, which is led from the tail of the first to the mouth of the second. If two of these pieces are made to revolve on the same spindle *in opposite directions* a very magnificent brilliant sun will be formed, throwing a circle of rays 20 feet in diameter. The accompanying sketch (fig. 55) will, I trust, make these directions sufficiently intelligible.

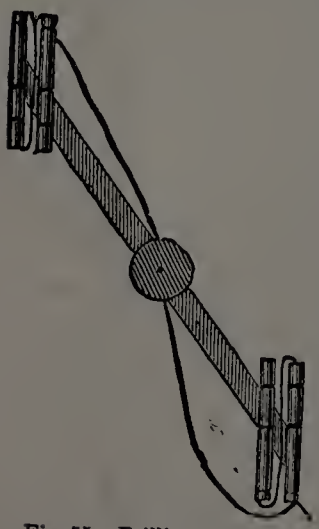


Fig. 55.—Brilliant wheel.

A fixed sun may be made with any number of brilliant cases arranged as the radii of a circle, and connected at their mouths with quick match. But since pieces of this kind may be rendered so much more effective by the addition of other fireworks, it will be useless for me to give drawings of them here. At the point I have sufficiently advanced in this subject to enable you to complete these exhibition pieces in all their beauty I have furnished some designs, from which you may perhaps derive a few useful hints.

I have now, I think, opened to you a wide field for experiment, your success in which depends now upon a careful following out of my directions, and upon the amount of taste and ingenuity of which you are master.

Mr. Newman will supply you with any of the tools mentioned, and either Mr. Darby, or Messrs. Bolton & Co., with any of the ingredients for your compositions; and if you have

Fig. 72

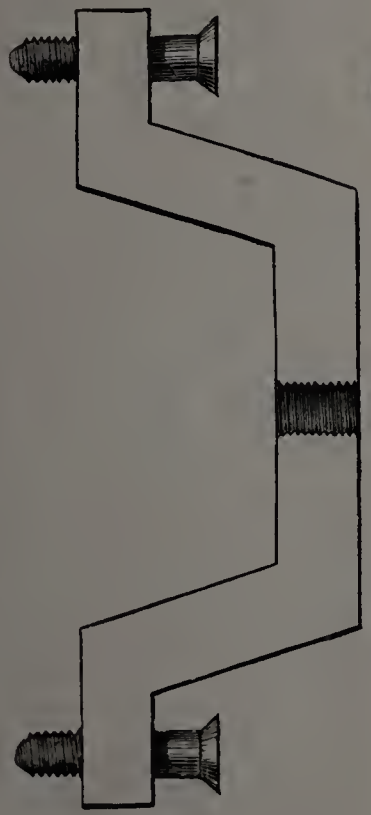


Fig. 71.

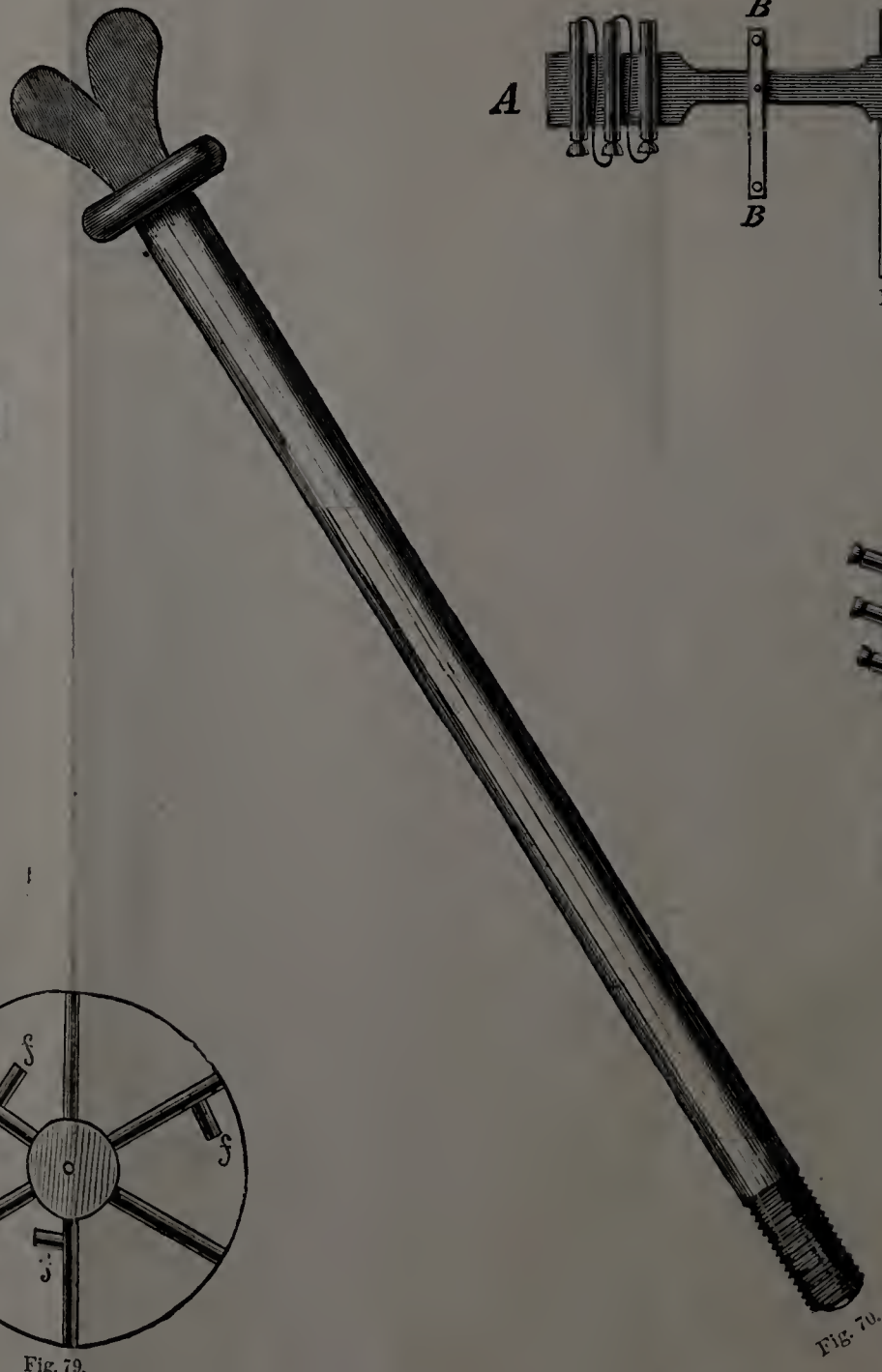


Fig. 70.

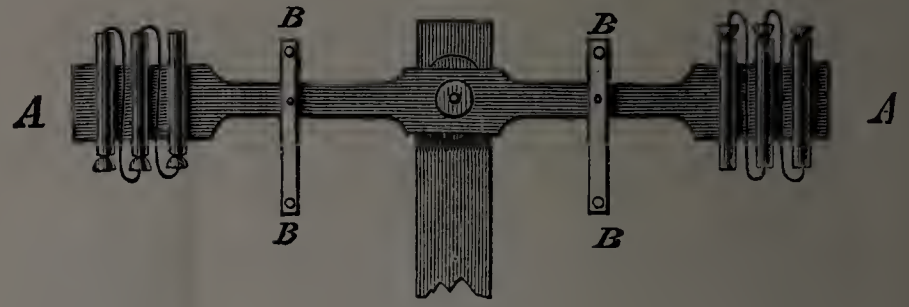


Fig. 76.

Fig. 78.

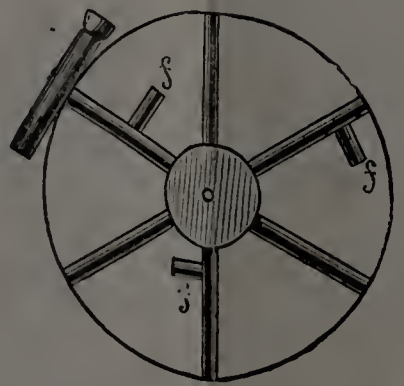


Fig. 79.

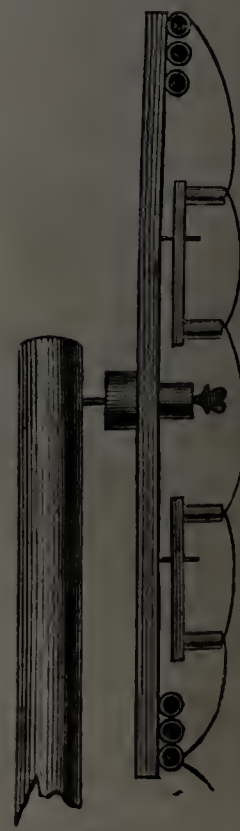


Fig. 77.

not fairly astonished your friends on some festive occasion, I do not think the cause will rest with me.

Do not forget the preparatory half-ladleful of slow composition in your cases of brilliant and Chinese fire.

Do not be careless about the manner in which your cases are *primed.* You would feel very foolish if, in firing a five pointed brilliant star, for instance, like the one sketched above, one or two of your cases were not ignited by the quick match.

Do not be in a hurry about making your frames. A framework for any piece, once well made, will last for ever. Remember that the concussion from your reports will be an excellent test of the strength of your woodwork.

Lastly, run no risks. Strong compositions have a way of behaving in a very awkward manner if they take fire unexpectedly, or at the wrong time; never, therefore, make compositions till the cases are ready to receive them, and you have time to ram them. And, above all, never leave batches of composition about, for the temptation is very strong to inquiring minds to experiment upon their powers of combustion.

WHEELS OF VARIOUS DEVICES, HORIZONTAL AND VERTICAL.

44. You will do well to remember that the remarks that I have already made, under other heads, concerning *device* are especially applicable to the subject of wheels. I am not giving you designs to lead you to suppose that this or that is *the* way of accomplishing any one object. There is no limit to the methods by which you may work out any plan, and this you will discover by degrees, as your knowledge of the art of pyrotechny grows riper, and your hands become more dexterous, and your manipulation consequently more easy.

But in the outset of our subject, let me advise you not to attempt to make catherine-wheels—that is, those small spiral wheels which are made by the professionals to sell on the Fifth of November, and seem to be intended for little girls to fire. You have nothing to do with such pieces as these. Your object is to provide *an exhibition*, and you will find it worth your while to bear in mind that the fireworks made by professionals are of two kinds—those made for their *retail* business, which consists for the most part of *small* single pieces, and which are papered up very neatly for sale, and those which they prepare for their large exhibitions, and which are in many instances made in an entirely different way from the former. Catherine-wheels cannot, as far as I can see, be employed in combination, and on this account they can form no part of our present work. I am very ready to allow that, when properly made, they are very pretty little things, but, not being available for our immediate purpose, they must be passed over here. In case, however, any one of my readers may happen to be so prejudiced in their favour that he cannot consider his exhibition perfect without them, I may as well say that he can procure them of Mr. Darby quite as economically as he can make them himself, for the rolling and the filling of their cases involves an expenditure of time and the acquisition of a certain "knack," which, when we consider that the wheel *will only do one thing* after all, seems like a wilful waste of such perseverance as might be directed much more profitably to some worthier object.

Now, the wheels of which I am about to treat are such as are made by tying on choked cases, filled with a strong composition, to frames of various forms, in such a manner that the recoil of the case during combustion shall have the effect of driving the wheel. The preparation of the composition for this purpose, and the making and filling the cases

are exceedingly simple: and, in fact, the only part of wheel-making which requires any degree of nicety is the preparation of the woodwork; for, unless the framework of the wheel be tolerably well balanced, and made to run easily and smoothly on its axis, much of the intended effect of your piece will be lost.

But we had better begin with the cases and compositions, and then proceed to consider the various modes of combination in which they can be employed.

The cases that I use for wheel purposes are of two sizes only—the 2-oz. and the 1-oz. size; and of these two sizes, the one far most commonly useful is the 1-oz. Cases of the 2-oz. size are necessary only for large wheels, where a considerable weight of material has to be set in motion. I make both these sizes of cases of the same length—that is, about $5\frac{1}{2}$ inches long.

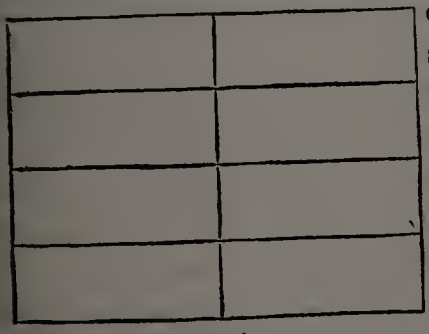


Fig. 56.

The paper for the 2-oz. wheel-cases is to be cut as follows:—Divide each sheet of 70-lb brown paper into eight equal pieces (see fig. 56), and then divide each sheet of imperial board into ten equal strips. Then proceed to make your cases, pasting and rolling them in precisely the same manner as previously directed, taking especial care that the inner fold of the paper, which lies next the former, is thoroughly saturated with paste, so that it is not loose when

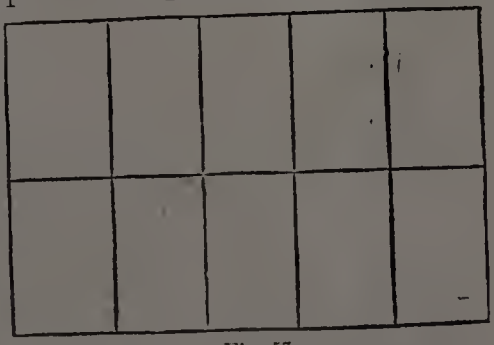


Fig. 57.

the former is drawn out of the case. If this inner edge be left loose, the composition will get behind it, and, upon firing the case, will act as a quick match, and infallibly burst the whole, and destroy your piece, and not only your piece of pyrotechny, but also your peace of mind; so do not fail to remember this hint.

Your 1-oz. cases for wheels must be made in the same manner, and with the same care. But your imperial board must be cut differently. Cut your 70-lb. paper in the same manner as directed above for 2-oz. cases—into eight equal strips—and your board into pieces of half that size—that is, into sixteen pieces. These divisions will give you cases quite thick enough for all purposes. Of course, each case is to consist of one piece of board and one strip of paper.

You will require no more tools for the filling of these cases than those already mentioned. The operations of choking and ramming are to be performed in the same manner as directed for cases of brilliant and Chinese fire, and the same blocks and nipples are to be employed.

We now come to the compositions with which the cases are to be filled. For these I give you several formulæ, in order that you may be able to vary your fires acccording to taste.

No. 1.

Meal-powder	16 parts.
Steel filings	4 „

This is the brilliant composition given in paragraph 41, which is used also for wheels with excellent effect.

WHITE FIRE.

No. 2.

Meal-powder.	16 parts.
Sulphur	3 „

Or,

No. 3.

Meal-powder	16 parts.
Nitre	4 „
Sulphur	2 „
Charcoal (No. 2)	2 „

Or,

No. 4.

Meal-powder	20 „
Charcoal (No. 2)	4 „

Or,

No. 5.

Meal-powder	16 „
Fine litharge	3 „

Or,

No. 6.

Meal-powder	40 „
Nitre	20 „
Sulphur	4 „
Charcoal	3 „
Bright steel filings	6 „
Litharge	2 „

Or,

No. 7.

Meal-powder	16 „
Nitre	2 „
Sulphur	2 „
Charcoal (No. 2)	2 „
Glass dust	2 „

Of the above compositions, Nos. 1, 2, and 4 will be found the most generally useful; and of these I prefer No. 4 for all ordinary purposes.

Remember that the compositions for wheel-cases are by far

the strongest that are used in the whole range of pyrotechny, and that they must on that account be compressed very evenly and completely in the cases, or they will burn too rapidly, and explode when ignited.

You will find it very advisable to ram a small quantity of the preparatory composition, recommended in paragraph 40, into the cases before putting in the wheel-case composition which you have selected. The cases should be filled till the composition rises to about half-an-inch from their ends—that is, half-an-inch at the end of the case should be left unoccupied by the composition. They should be primed with wetted meal powder as soon after they are filled as convenient, care being taken that the space which the point of the nipple occupied during the operation of ramming is filled up by the priming.

Fig. 58.

When the filling and priming of all your cases is accomplished, you will next have to cover them with paper which shall project about an inch beyond each end of the case. The object of this is to enable you to tie in the quick-match which is to connect one case with another. This operation is very easily performed. Cut some ordinary newspaper into strips wide enough to project an inch over each end of your case—that is, *about eight inches wide*—and long enough to go two or three times round the case. It will not be necessary to paste the newspaper strips *all over*. If they are pasted slightly *at each end* it will be quite enough. The paste at one end of the strip will stick it to the case, and that at the other end will fasten it down so as to prevent it from coming unrolled. The annexed sketch (fig. 58) will show you how the case ought to be covered.

COMMON SINGLE TRIANGLE WHEEL.

45. Now, the first form of wheel of which I shall speak is that usually known by the name of the "*Common Single Triangle Wheel.*" Its manufacture is very simple. Provide a piece of light beech wood, of hexagonal form, each of whose sides is two inches in length (fig. 59).

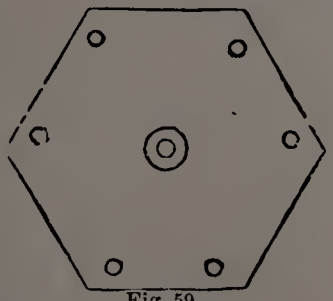


Fig. 59.

This hexagonal piece of wood may be about half-an-inch thick. Then bore through its true centre a hole about three-quarters of an inch in diameter, into which glue firmly a piece of wood turned or cut to the shape given in the drawing (fig. 60). Through this piece bore, *in its exact centre*, a hole about a quarter of-an-inch in diameter, and, when bored, burn it through with a piece of quarter-inch iron rod, red hot. This is the hole through which the spindle is to pass which is to form the axle of the wheel. When the operation is finished, the side view of your framework will be like the accompanying sketch (fig. 61). The object of this centre is twofold; first, to obtain a greater steadiness in the motion of the wheel, by increasing the length of the hole through which the spindle runs; and, secondly, to keep the wheel, during its revolutions, from touching against the post into which the spindle is driven—*a*

Fig. 60.

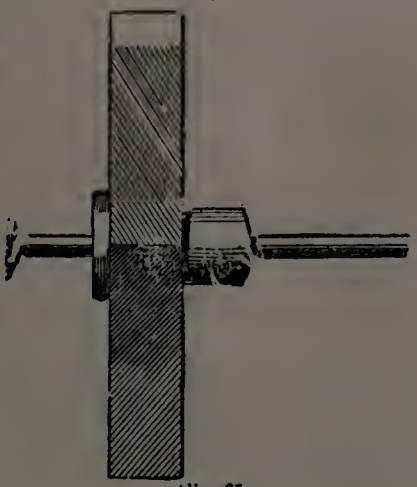


Fig. 61.

precaution never to be forgotten in the case of vertical wheels of all descriptions.

I must next suppose you to have three cases of the 1-oz. size ready filled and primed and papered. Before fastening these on your framework *take especial care that the one which is to burn last has its end stopped up with some incombustible material.* The best plan is to ram some powdered clay upon the composition before removing the case from the nipple, in the same manner as recommended for the ends of rockets. If some precaution of this kind be not taken, the fire issuing from the mouth of the first of your three cases will be communicated to the tail of the third, and thus bring your wheel to a most inglorious end.

Having, then, taken this precaution, proceed to tie on your cases to the edge of your wooden framework. This is easily done if you bore two holes, through which your string can pass, close to each of those sides of the frame on which the cases are to lie. A reference to the sketch of the framework (fig. 59) will show you where these holes should be made.

In tying on your cases, be quite sure that the mouths or choked ends of them lie all in the same direction, in such a manner that the tail of the first case reaches almost to the mouth of the second; the tail of the second to the mouth of the third; the tail of the third to the mouth of the first. When you have secured them firmly in their places with string, you can then proceed to connect them with quick-match—or *clothe* them, as it is called—so that when one case is burned out it will communicate its fire to the mouth of the next, and so on till they are all consumed.

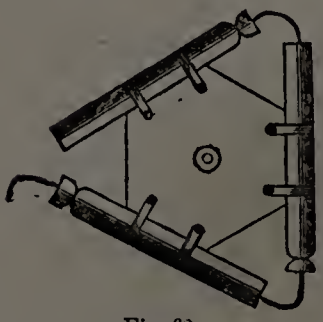


Fig. 62.

In cutting your quick-match, bear in mind that about an inch of the black match itself must project uncovered beyond each end of the paper tubes in which it burns. This is to insure its taking and communicating its fire. In the annexed sketch (fig. 63) you will see represented a piece of quick match

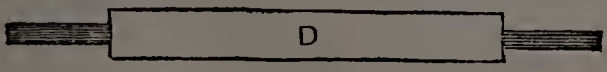


Fig. 63.

as it should be cut for connecting cases. At fig. 64 is represented a wheel-case, such as is to burn second in your single

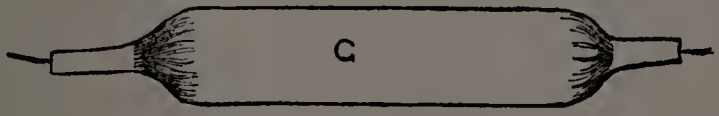


Fig. 64.

triangle, and has a piece of quick-match, like fig. 63, at each of its ends, to connect it with the first and third case on the wheel. You will observe that the newspaper which projected beyond the ends of the case is simply tied in tightly round the quick-match. You will, after a few trials, be able to get through this "clothing" operation very easily, and with no unnecessary wasting of quick-match.

The mouth of your first case may either be finished off with touch-paper, or may have a short piece of quick-match put into it, to be lighted with a port-fire.

Your wheel is now completed and ready for firing. But I may as well suggest here that its beauty and effectiveness will be very much enhanced if the three cases on it be filled with different compositions. For instance, fill the case *which is to burn first* with composition No. 2; that which is to burn second with No. 4; and the third case with No. 1. This plan of varying the compositions, or any other that suggests itself, may be adopted in the case of *all* wheels. It is necessary,

however, that you should be well acquainted with the character of each composition, in order that you may be able to produce the exact effect that you require at the right time.

Composition No. 1 gives only brilliant sparks, and must be prepared as shortly as possible before use.

Composition No. 2 will give a whitish circle of fire fringed with red sparks.

Composition No. 3 produces less white flame and more sparks than No. 2.

No. 4 is a sparkling composition; by far the best for general use, in my opinion.

No. 5 gives reddish sparks, which fly off in very straight lines from the wheel, and form rays, as it were.

No. 6 gives rays, brilliant sparks, and a centre circle of white fire.

No. 7 gives a moderately good centre, with drossy red sparks of a peculiar shape.

Those compositions which throw out the greatest number of sparks during combustion are the best for larger wheels, but will be found also very effective in the common single triangle.

Those which have a tendency to produce a *flame*, rather than a *jet of sparks*, are very effective as a variety for *small* wheels, but produce an effect comparatively poor when employed for those of greater dimensions.

For *horizontal* wheels, *sparkling* compositions alone are effective, because in them everything depends upon the form that the fire assumes *in its outline*, and not upon the shape of the wheel itself. Compositions which produce but few sparks would be entirely out of place if used to turn horizontal wheels.

DOUBLE TRIANGLE WHEELS.

46. I will now offer a few remarks with respect to the construction of the *Double Triangle Wheel.* This piece may be made by employing two hexagonal frames of wood of the same size, in a centre twice as long as that described in fig. 60. But it may also be made in such a framework as Mr. Darby will supply, which is a nave made of light wood, with six spokes, cut at their ends in such a manner as will allow the cases to be firmly attached. But whether you use the one form or the other, the principle is precisely the same, and the cases must be arranged as shown in the adjoining diagram (fig. 65).

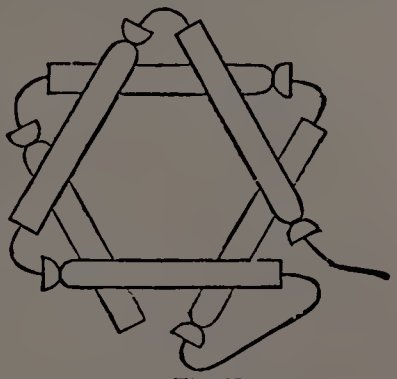


Fig. 65.

The performance of this wheel is, of course, the same as that of the single triangle wheel, and differs from it only in the matter of duration. But it must be borne in mind that a double triangle wheel, having six cases upon it, would be a very slow sample of pyrotechnic beauty *if all these cases were filled with the same composition.* It would, indeed, be a most meaningless performance. You must therefore take care that some variation is made, using at least two varieties of composition. You will then have an effective piece, capable of lasting a long time in proportion to its size.

VERTICAL WHEELS.

47. Leaving now the triangular form of wheels, we will pass on to those which are called *Vertical.* All triangle wheels are vertical wheels, but all vertical wheels are not

triangular; it is of non-triangular vertical wheels that I am now about to speak. These are made with a nave, spokes, and felloe in the same manner as a carriage wheel. The cases may be fastened to the felloe, or the wheel may be made without a felloe, and the cases fastened, in any way that occurs to you, to the extremities of the spokes; either by nailing to their ends pieces of wood at right angles with the spokes, or by cutting a groove in the end of each spoke and tying a case into it with string. As long as the cases be properly arranged and secured firmly to the framework it matters very little which of the above plans is adopted. Select the plan which can most easily be carried out by the means that you have at command, and carry it out in the simplest possible way. Complications are not only unnecessary, but very likely to deprive your pieces of what would otherwise have been their complete success. The accompanying sketch (fig. 66) gives you a representation of another arrangement of six cases, which is, in my opinion, productive of a better effect than the double triangle. The wheel here represented is vastly improved by the addition o a coloured fire placed somewhere near its centre; but I have not yet given any directions or instructions for the preparation of colours for such a purpose, and the making of these additions must be reserved for its proper place.

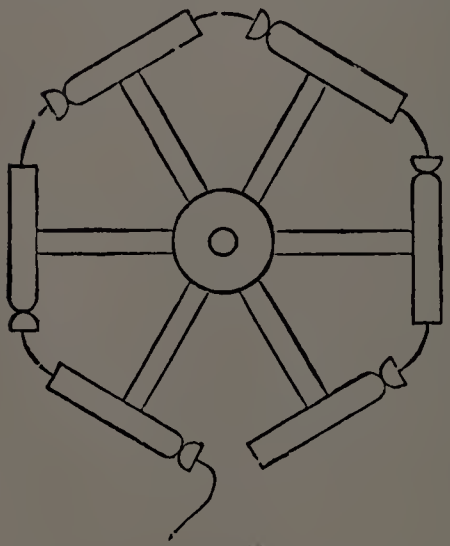


Fig. 66.

But perhaps the most satisfactory arrangement of six cases on a vertical wheel is that which the next sketch represents.

By the plan adopted there—*that of making the cases incline outwards*—a much larger circle of fire is produced, and the general effect is considerably improved. It will be perceived that the mode of "clothing," and tying on the cases, for all these different forms of wheels is the same, the only difference being in the shape of the framework. The cases may be fired singly or doubly in this wheel — that is, you may make them burn one at a time till all are consumed by putting the quick-match to them just as my sketch (fig. 67) represents, or you may connect with quick-match the first and fourth cases, so that these take fire simultaneously. By this arrangement the first and fourth cases will work together, the second and fifth, and the third and sixth. Of course the first and fourth cases are the only *pair* that need be connected by quick-match, for they will severally convey their fire to the second and fifth, and these to the third and sixth. The framework of this wheel may be made of deal or beech (the latter I should prefer) about three-eighths of an inch thick; the wheel altogether should be from 15 to 18 inches in diameter. It should by all means have some centre, like that described at fig. 60, to secure its steady and true movement. This wheel also will be vastly improved by the addition of a coloured fire to its centre.

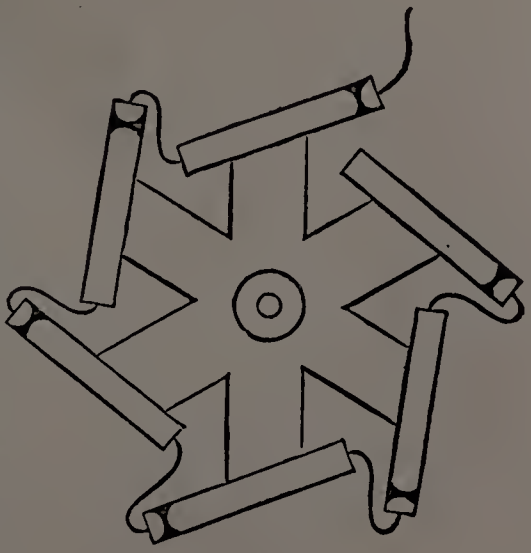


Fig. 67.

We will now proceed to speak of

HORIZONTAL WHEELS.

48. These, like the vertical wheels, may be made of almost any shape or design. They have a hole bored in the exact centre of their nave, and up this hole the spindle passes on which they revolve.

The annexed fig. 68 gives you one of the simplest forms of the horizontal wheel. A wheel made according to this plan will require four wheel-cases and a case of Chinese fire long enough to last during the combustion of two of the wheel-cases. The quick-match is put to it in the following manner: — Simply connect the first and second wheel-cases by carrying a quick-match from the tail of the first to the mouth of the second. Then from the tail of the second carry two "leaders" (as these pieces of quick-match are called), one to the third wheel-case and the other to the perpendicular case of Chinese fire, which will thus be ignited at the same moment with the third wheel-case; and to complete the wheel carry a leader from the tail of the third to the mouth of the fourth case.

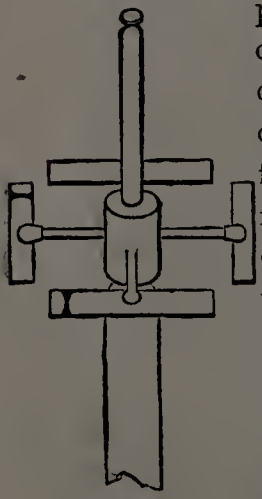


Fig. 68.

The case of Chinese fire which I should recommend you to make for this and for other horizontal wheels is one of the 2-oz. size, nine or ten inches in length, and filled with composition No. 4, given in paragraph 41. It is to be affixed to the wheel thus:—There must be a small projecting piece of wood left by the turner at the top of the nave of the wheel, about an inch in height and five-eighths of an inch in diameter,

and if an inch of the case be left unoccupied by the composition at its unchoked end, this end can be squeezed over the wooden point mentioned above, or can be glued on to it if you think it desirable.

Another and very amusing variety of the horizontal wheel is that which my next illustration represents, and which is sometimes called the "capricious" wheel. This carries six wheel-cases and one Chinese fire case. The wheel-cases are arranged in the following manner:—All the cases are placed at an angle with the plane of the wheel's revolution; the three upper ones have their mouths inclined upwards, the three lower ones downwards. Care of course must be taken that all the mouths, whether inclining upwards or downwards, be turned *in the same direction*. They are connected thus:—Make one of the lower cases the first to be fired; from the tail of this carry a leader to the nearest of the upper cases, which will then burn second; from the second carry a leader to another of the lower cases; then from this to another of the upper ones. From this fourth case carry three leaders—one to the remaining upper case, one to the remaining lower case, and one to the case of Chinese fire.

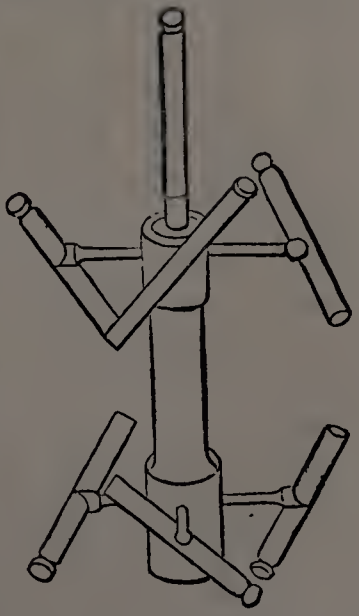


Fig. 69.

The effect of this wheel is exceedingly laughable. It does not revolve so rapidly as the simple horizontal wheel mentioned above, the cases of which are perfectly horizontal. The impression that its performance always gives one is, that it is determined to do something violent; that if one direction of

fire will not answer it will try another. Each succeeding case sends it round more rapidly than the last, on account of the decreasing weight as the cases burn out; and if the two cases which are to burn with the case of Chinese fire be filled with composition No. 1, given in paragraph 44, the fury of the wheel will at the last seem to know no bounds.

It is necessary, however, to see that the hole into which the iron spindle is to pass is truly bored and is long enough, and that the spindle *at the top* of the post is straight and strong. This spindle should pass into the nave of the wheel five inches at least.

Let me press upon you one or two important hints. *The case, or cases, that burn last on each wheel must always have their ends closed with clay, or some incombustible substance.* If this advice be neglected your wheel is pretty certain to fail.

I have drawn at fig. 70, a fac-simile of the spindle which I use for all vertical wheels. It is made to screw into an iron which is represented at fig. 71, which iron is fixed by screws to my post in the manner shown at fig. 72. The post I employ stands about ten feet out of the ground. Into its top is driven another spindle, on which my horizontal wheels turn. Both these iron spindles should be made of quarter inch iron rod.

You will find the spindle drawn at fig. 70 very much more convenient than one simply driven into the post, and having a "nut" at its end to screw and unscrew; for it is more than probable that on a dark night, when you are taking down one wheel that has been fired, and putting up another, you will drop the "nut," and feel considerably at a loss without it. And besides this, you can by this means always remove the spindle, and protect it from rust. Your post should be very steady.

Mr. Darby will supply you with any frameworks of wheels, made to any pattern that you please.

I shall speak of some other wheels when we are sufficiently advanced in pyrotechnic proficiency to be able to attempt the manufacture of *all* their component parts.

LANCES—WHITE AND COLOURED.

49. We have now, in the course of our pyrotechnic investigations, arrived at a point where it becomes necessary to know something more than we have already learned about *coloured fires*. I have spoken hitherto only of those coloured compositions which are employed in the manufacture of rocket and Roman candle stars. These compositions must for the most part be confined in their use to that purpose, because they are, in almost all cases, far too rapid in their combustion for the purposes of which I am now about to speak.

I now proceed to treat of Lances, white and coloured, for making up devices, such as names, crests, mottoes, wreaths, &c., &c.

Now, there are a great many formulæ given for compositions employed to decorate other fireworks, or to form designs of any kind in white or coloured fire, with which it may be advisable for my readers to be acquainted, in order that they may have the opportunity of selecting for themselves, and of providing themselves with, a colour of that particular shade and character which is best adapted for the working out of the design determined upon.

In the first place I will speak of those fireworks which are properly called "lances." These are small cases, generally made about three-sixteenths of an inch in diameter, that is round a piece of glass or brass rod or tube of that size (tubes are always best for these small formers). The cases are about

two or two and a half inches long, with one end pinched or turned in. Two rounds of thin demy or double crown white paper, pasted, will give sufficient thickness and substance for the case. The cases, when dry, are to be filled with either of the following compositions by means of the funnel and wire apparatus illustrated at figs. 34 and 35 :—

COMPOSITIONS FOR LANCES.

White.

No. 1.

Nitre	16 parts.
Sulphur	8 „
Meal-powder	6 „

Or,

No. 2.

Nitre	16 „
Sulphur	4 „
Meal-powder	6 „

Or,

No. 3.

Nitre	12 „
Sulphur	4 „
Sulphide of antimony	3 „

Or,

No. 4.

Nitre	72 „
Sulphur	18 „
Regulus of antimony	33 „
Realgar	1 part.
Shellac	1 „

Or,

No. 5.

Nitre	96 parts.
Sulphur	24 „
Regulus of antimony	48 „
Realgar	6 „
Shellac	1 part.

These for the most part give a bluish-white flame, and when employed in cases of the size mentioned above, burn slowly, and will last as long as this species of firework is required to last.

Yellow.

No. 6.

Chlorate of potash	72 parts.
Oxalate of soda	60 „
Stearine	6 „
Sulphur	6 „

Or,

No. 7.

Chlorate of potash	40 „
Oxalate of soda	16 „
Shellac	8 „
Stearine	3 „

Green.

No. 8.

Chlorate of potash	60 „
Nitrate of baryta	41 „
Calomel	49 „
Powdered sugar	30 „
Shellac	1 part.

Or,

No. 9.

Chlorate of potash . . .	63 parts.
Nitrate of baryta	50 „
Calomel	50 „
Sugar	32 „
Shellac	1 part.

The green colour is never very decided when the compositions are employed in cases so small as those spoken of above. But by far the best composition to be used in these small cases is one containing a rather costly ingredient, which is the chlorate of baryta. The usual price of this salt is about 8s. per lb., or rather less. It gives a magnificent colour if it is pure, but if not, it is not worth buying. I give you the formulæ in which it may be employed, in case you should require a very brilliant emerald green in these small lances. They are—

No. 10.

Chlorate of baryta . . .	18 parts.
Calomel	7 „
Shellac (very fine) . . .	3 „

Or,

No. 11.

Chlorate of baryta. . .	24 „
Stearine	3 „
Sugar (very fine)	1 part.

Compositions containing chlorate of baryta are perfectly safe *where no sulphur is employed*. The salt itself is not at all deliquescent. A very good formula besides the above is one containing three proportions of chlorate of baryta, and one of powdered sugar. We will next speak of RED LANCES.

Red Lances.

No. 12.

Chlorate of potash	13 parts.
Nitrate of strontia	10 „
Calomel	8 „
Shellac	3 „
Dextrine	1 part.
Chertier's copper	1 „

Or,

No. 13.

Chlorate of potash	12 parts.
Nitrate of strontia	12 „
Calomel	6 „
Shellac	4 „
Chertier's copper	1 part.
Charcoal (fine)	1 „

A good rose-coloured fire may be produced by a composition containing the oxalate of strontia, which, though not to be met with everywhere, is a valuable salt on account of its extreme dryness and fineness. The formula given next has the merit of being rapid in its combustion. Should it be thought *too quick*, decrease the proportion of chlorate of potash, or increase that of calomel. The increase of calomel has the effect of deepening the colour, but, at the same time, of diminishing the reflective power of the light.

Rose-coloured Lances.

No. 14.

Chlorate of potash	24 parts.
Sulphur	2 „
Stearine	3 „
Oxalate of strontia	4 „

This composition will remain good for any length of time, and has therefore a great advantage over those which contain the nitrate of strontia. And here I may as well remind you of the importance and necessity of having this latter salt perfectly dry and fine, otherwise you will be disappointed of your intended effect in the ordinary red-fire compositions.

For the blue lances you may use composition No. 8, given in paragraph 23.

But there are also two other formulæ which you will find very serviceable and effective :—

No. 15.

Chlorate of potash . . .	32 parts,
Chertier's copper	12 „
Calomel	40 „
Sugar	25 „

Or,

No. 16.

Chlorate of potash. . . .	6 „
Chertier's copper	1 part.
Calomel	5 parts.
Sugar	4 „

For the preparation of a purple fire for these little cases, you cannot do better than use that given for Purple Rocket Stars.

There are still two other colours which you may perhaps find useful and ornamental, and without which my list would not be complete. They are the violet and the lilac tints. The violet is at No. 17, and the lilac at No. 18 :—

No. 17.

Chlorate of potash . . .	26 parts.
Calomel	24 „
Carbonate of strontia . . .	4 „
Chertier's copper	3 „
Sugar	14 „

Or,

No. 18.

Chlorate of potash . . .	12 „
Prepared chalk	4 „
Sulphur	5 „
Calomel	3 „
Sulphide of copper . . .	10 „

With regard to the use of sugar in pyrotechnic compositions it must be borne in mind that it is a substance which readily attracts damp, so that it must be kept in a closely-corked or stoppered bottle. It should be reduced to powder in a very dry mortar, and then sifted through very fine muslin, to fit it for pyrotechnic uses. And the mention of muslin here reminds me of a fact which experience has brought to light, and which you will find it highly convenient to remember. All those powdered salts and pyrotechnic ingredients which clog the meshes of a wire sieve will easily pass through a sieve made of muslin. For instance, powdered stearine, shellac, sugar, and the salts of strontia and baryta will be found to sift much more readily through muslin, *provided the muslin be dry and clean.* This will enable the amateur pyrotechnist to fit himself up with sieves of any fineness at a very small cost. He will require only a tin or zinc drum, about 6 inches in diameter, and 4 inches high, with a wire ring round each end. Over one of these ends he can stretch a piece of muslin of the required thickness, and fasten it with a strong elastic band. Or he may have a metal ring made large enough to fit over the muslin and round one end of the drum, which he can remove when a change of muslin is necessary. I do not by any means recommend this kind of sieve for sifting such things as meal-powder, charcoal, or sulphur; for I consider a receiver, made to fit on to the sieve, indispensable in the case of sifting these articles. The dust arising from this operation will

otherwise find its way into your eyes, and nose, and clothes, and over everything in your room.

It is, perhaps, unnecessary for me to add that all the above compositions must be made up with the greatest exactness, and no ingredients must be used but such as are thoroughly dry and in the finest powder. The most successful pyrotechnists have never been able to produce proper effects, even with the purest and best materials and chemicals, unless those materials have been first reduced to the necessary state of fineness and dryness, and then mixed till they have become most intimately incorporated.

We will now suppose a sufficient number of these lances to be filled with the selected compositions. They must be primed precisely in the manner described under the head of "Golden Rains." When finished they will be about two and a-half inches long, and about equal in size to an ordinary drawing-pencil.

The first thing to be done is to decide upon your design. This, I presume, will not be very large. I need not furnish you with a series of suggestions for these designs, for the chance is, that, after all I can say, the one which you wish to execute will be one of your own conception, or at all events, one which you would rather carry out in your own way. But I give here a plain sample of the

Fig. 73.

work (fig. 73), which is merely intended to make clearer my verbal directions. *The letters should not be less than ten inches high.*

In the first place you must either procure a board of sufficient size for your design, or you must make a wooden framework of the shape that you require. Suppose the design to be a V.R. : now either sketch this out upon one side of your board, or, if you wish to have it larger than a board will allow, make a plain rough framework describing the letters. When this is done, decide upon the distance at which you can place the lances one from another. This distance is generally about two inches, but no exact rule can be laid down, for so much depends upon the sort of design that you think of executing, and upon the scale of its size.

I will now suppose that you have your design carefully drawn upon the board or framework. Upon the outlines of your sketch make little pencil circles wherever you intend to place a lance; and, as far as it is possible, arrange that the lances shall be equidistant one from another. Of course the prime object of the arrangement must be to make the outline of the letters, figures, &c., as plain and bold as possible. Now with a centre-bit, or, what is better, a pin-bit, *bore a hole about a quarter of an inch deep* where your circles are pencilled. These holes must be of such a size that the closed ends of the lances will fit easily into them. When you have completed this operation, get either some glue or some of the mixture of size and red lead which I have recommended before; and when it is liquid, dip into it the closed end of each of the lances. Enough of the mixture will adhere to the lances to allow of their being secured firmly in the holes that you have bored. In a very short time all will be hard and dry, and you will then have a series of lances projecting at

right angles with your board or framework, each having its mouth primed, and all being of the same length.

The only thing that remains now to be done is to clothe these primed mouths with quick-match. This is by no means difficult, but requires a certain amount of patience. Take a length of match in its case, and, having exposed one end of the black match itself, put a small pin through it into the priming of one of the lances. This will fasten it down, and at the same time will insure its ignition. Then lead the quick-match on to the next lance, cutting away with scissors a piece of the under side of its case, to allow the match in passing to touch its priming. Put a pin through the match into the priming of this lance also, and so on till all are clothed. If more of the casing of the match has been cut away than is necessary, it will be well to paste small strips of paper wherever this has happened, as any exposure of the black match will endanger the piece, rendering it liable to ignition from the sparks of other fireworks. This piece of caution must be carefully attended to, because lance-work is generally employed with the final of an exhibition, when a great many pieces are going off at once, and when the effect of the whole may be easily spoiled by the untimely firing of one part.

The arrangement of colours in lance-work must, of course, be left entirely to the artist himself. It matters not what the arrangement is, if the colours be only properly contrasted. Remember that the most effective and striking contrasts are blue with yellow, red with green, purple with red, white with violet or red.

In the case of letters, or a monogram, a border of an oval or circular shape adds very much to the effect. This border should be of a different colour to that used for the letters, &c.

Lance-work is not very largely used in pyrotechnic ex-

hibitions; one specimen of it in each display is quite as much as is generally seen. But it certainly is a pyrotechnic feature, and on that account must not be passed over. Lance-work is generally accompanied in its exhibition with Roman candles, or with some arrangement of gerbes to take off what would otherwise be its bare appearance. When introduced as a centre to some framework of sparkling fire it is very beautiful, particularly if colours be employed in it.

I need hardly add that when it is fired the framework is to be placed vertically, and *the lances are to burn horizontally.* It is a good plan to paint the framework black.

COLOURED LIGHTS.

50. We may now go on to deal with another branch of this part of our subject—viz., that which concerns the manufacture of coloured lights for illuminating wheels, or set-pieces, or any larger kind of firework. This species of colour is perhaps more useful in exhibition work than any single firework that can be named, for there are few set-pieces, or wheels, or designs of any pretentions to which these coloured lights cannot be adapted, and adapted, too, with a very enhancing effect.

Their preparations is exceedingly simple. They are generally made in two sizes only; these are the two-ounce and the one-ounce sizes. The cases are made of cartridge or foolscap paper and are about two inches long for the two-ounce size and one inch and three-quarters for the one-ounce size. Used-up copy-books furnish excellent paper for making these coloured-light cases. Three or four rounds of the paper will give you ample thickness for the case. The paper should be pasted *all the way along the strips.* When the cases are thoroughly dry, ram into the bottom of them some dry powdered clay; this will make a close end, and will also

furnish an imcombustible part by which the case may be tied or fastened to its place. The clay is often rammed so as to fill the case nearly half-way up ; but, of course, the space left for the composition will depend upon the length of time that you wish the colour to burn.

There is some exactness and nicety, besides a certain amount of actual experience, required for the proper adjustment of these colours to the cases in combination with which they are to burn. The coloured light should be under control, so that it makes its appearance and introduces its intended effect at the right time, and lasts only as long as it is required to last. I will now give a few formulæ for these larger coloured lights. These, if made up with ordinary care and their ingredients thoroughly mixed will produce magnificent colours, both as regards depth of tint and brilliancy of reflective power. The compositions given above for lances are for the most part of too rapid combustion to answer well in these larger and more open cases, but the following will be found to succeed admirably if the chemicals used be only pure and dry, and properly incorporated :—

WHITE LIGHTS FOR DECORATION.

No. 19.

Nitre	4 parts.
Sulphur	1 part.
Sulphide of antimony . . .	1 „

Or,

No. 20.

Nitre	4 parts.
Sulphur	1 part.
Meal-powder	1 „

These will give the ordinary bluish-white light, and compositions made from them will remain good for any length of time.

The yellow lights may be made from the formulæ given under the head of Lances.

The following will produce the *green*:—

No. 21.

Nitrate of baryta	80 parts.
Chlorate of potash . . .	32 „
Sulphur	24 „
Calomel	16 „
Charcoal (fine)	3 „
Shellac	2 „

The drawback to all green colours burnt in cases is that the combustion of the case itself impairs to some extent the purity of the tint of the flame. Cases, therefore, which are to contain green fire must not be made unnecessarily thick. Composition No. 21 gives by far the best colour that I have yet seen for this purpose, and when contrasted with a good red is all that one need desire.

The two next compositions will furnish exceedingly beautiful red colours. It is best to make them up only a short time before using them, as their effect is much more brilliant when quite freshly mixed; and, besides, the nitrate of strontia becomes damp after a time, particularly in the autumn and winter months, in which case it will produce only the effect of disappointing you. The compositions are both perfectly safe, since they contain no sulphur, and are on that account entirely free from all liability to spontaneous combustion:—

Red Lights.

No. 22.

Chlorate of potash . . .	32 parts.
Nitrate of strontia . . .	48 „
Calomel	20 „
Shellac	12 „
Chertier's copper	4 „
Charcoal (fine)	1 part.

Or,

No. 23.

Chlorate of potash . . .	84 parts.
Nitrate of strontia . . .	80 „
Calomel	51 „
Dextrine	22 „
Shellac	18 „
Chertier's copper	4 „

Of these two formulæ, No. 22 is the one that I generally employ. It produces a very brilliant colour, which is *almost scarlet*, and forms, in my opinion, the best contrast both to the green and purple lights. No. 23 gives a deep rich crimson, which may also be found very effective occasionally. Dextrine, which enters into its composition, is always to be had in very fine powder, and therefore it will give you no trouble to bring it into the proper condition for use. It is very cheap, being sold generally at from 1s. to 1s. 6d. per pound. You will require only a very small quantity of it.

We now come to the last of our colours for making these decorating lights, and that is the purple.

Purple.

No. 24.

Chlorate of potash. . . .	28 parts.
Chertier's copper	28 „
Calomel	13 „
Shellac	8 „
Stearine	1 part.

Or,

No. 25

Chlorate of potash . . .	40 parts.
Calomel	28 „
Chertier's copper	28 „
Dextrine	10 „
Stearine	3 „

No. 26.

Chlorate of potash . . .	26 „
Chertier's copper	24 „
Calomel	14 „
Shellac	7 „

All of these three formulæ produce good colours. I think that I am rather inclined to give the preference to No. 25, on account of the very effective contrast that it makes when employed to burn with the red at No. 22. These three colours are perfectly safe, for the same reason that I stated above when speaking of the red lights.

I trust that the formulæ which I have now given will be found to supply all that you will require in this department of pyrotechny. The compositions have all been used by me, and I can therefore speak from actual experience of their respective merits, and so you will be pleased to remember that if they do not succeed in your hands the fault will lie either in the con-

dition, perhaps the impurity, of your chemicals, or in your own manipulation. I can answer for the receipts; all that is necessary on your part is a scrupulous attention to my directions.

And here let me put in a word of caution. Where you see "*Red Lights, Green Lights, Purple Lights*" written over the formulæ above, you are to remember distinctly that I use the word "LIGHTS" to distinguish this branch of pyrotechny, and these compositions, from those which I mean to treat of under the title of coloured "FIRES." By coloured lights I mean small cases, of the 1 or 2-oz. size, filled with either of the above compositions from No. 19 to No. 26 inclusive. *These compositions are not adapted for the purpose of producing coloured FIRES, such as are employed to light up gardens, avenues, buildings, &c.* They are to be confined to their own use, which is *the decoration of wheels, or of any large and complicated exhibition fireworks.* For this purpose they *will* answer *well*, and for the other *they will not answer at all.* And having now explained the distinction between coloured LIGHTS and FIRES, I must ask my readers not to lay the blame upon me if, when employing my compositions for purposes for which they were never intended, they find they do not succeed.

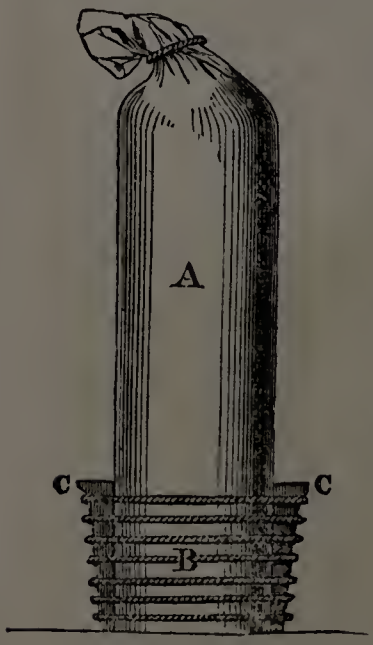


Fig. 74.

But we have still to speak of the way in which these coloured lights are to be fastened to the pieces which they are designed to decorate. The most common

way of doing this is to drive a nail into the wooden framework of the piece at the place where you wish to place the coloured light, and to tie the case which contains it to this nail. Two nails, like "two heads," are better than one, and the case may be secured as shown in the annexed sketch (fig. 74). A represents the coloured light case; B the string which is passed round its lower clayed end, by means of which it is secured to the two nails, C C, which are driven into the wooden framework. This mode of fastening is very simple and effective for attaching the coloured-fire cases to the framework of a *fixed* piece. But in the case of a wheel, or any piece which has motion, it is, in my opinion, very desirable to give them a position like that of the *wheel cases—i.e.,*

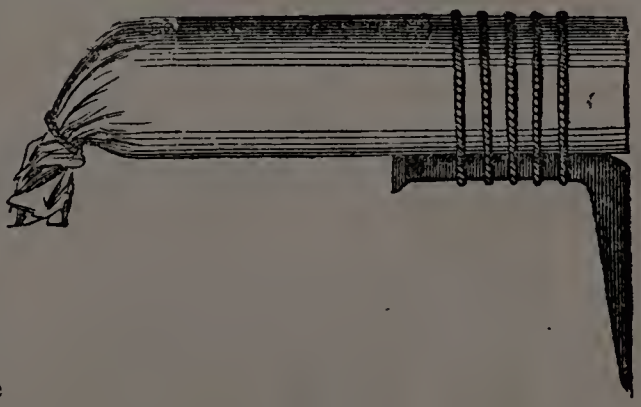


Fig. 75.

to let them revolve with their mouths in the opposite direction to that of the motion of the wheel. This is easily done, either by fastening them between the spokes of a large wheel, or, in the case of a small one, by driving in a longer nail than is necessary, and bending down the head of it in the desired direction, and fastening the coloured-light case to this bent part (fig. 75).

By this means you will have no difficulty in attaching these little decorations in any place, to any part of the framework of your piece, or in any direction. The object of turning the mouth away from the direction in which the piece moves is that the resistance offered by the air during its revolution

may not interfere with the easy combustion of the coloured light.

But we have yet to say a few words about the filling these 1 or 2-oz. cases, and their priming.

The compositions used for this purpose do not require, it must be remembered, to be *rammed* into the cases; they only need be *pressed in* so firmly that their motion during combustion shall not shake them out. Of course they should be *uniformly* pressed in, and this is simply done by pressing in only a small quantity at a time.

With regard to their priming, this may be done in either of the following ways—by smearing into their mouths some wetted meal-powder, or, what is better, by pressing into their mouths a piece of quick-match, and then pressing a little of the coloured composition over that, and allowing the end of the match to project about half-an-inch. But in whatever way they are primed they must have two rounds of some thin paper pasted round their mouths, and projecting an inch or so beyond them, into which the leaders can be tied which are to connect them with the other cases of the piece.

In the case of small wheels, in which only one of these coloured-light cases is to be employed, it will be advisable to fill it with compositions of different colours. Press in first enough red-light composition to fill one-third of the case; then enough purple to occupy another third, and fill the remainder of the case with green composition. By this means you will be able to vary your effects to any extent.

I now wish to give you directions for making a very beautiful and effective firework, in which these coloured lights play a prominent part. I must refer you to the page of illustrations which accompanies this paper, in order that you may have no difficulty in understanding the directions which I am now about to offer.

In its general working the piece is very similar to that which I have described under the name of "Brilliant Wheel" at paragraph 43. But it is at the same time a great improvement upon the one there spoken of. Cut a piece of deal or beech board into the shape drawn at *A A*. (fig. 76). This should be at least half-an-inch in thickness, and not less than three feet in length. When you have shaped it as you intend to leave it, find its centre, the point at which it balances. Through this point bore a hole of such a size as will easily admit the iron spindle which screws into your firework post (fig. 70). At each end of this wooden frame place three wheel-cases, taking care that the position of the mouths of these cases is so arranged that their driving power shall all be in one direction. A quick-match leader is to be carried from the *tail of the extreme case at each end to the mouth of the next*, and then from the tail of these to the mouths of the third at each end.

Two more pieces of wood (represented at *B B*. fig. 76) will now be required, each about twelve inches long, five-eighths of an inch wide, and three eighths of an inch thick. They must have a hole bored through them, into which a spindle or smooth round nail can pass easily. *But this hole must not be in their centre*; it should be bored about four inches from one end, which will leave eight inches on the other side of the hole. Through these holes drive a smooth round nail into the long framework of the piece, exactly half-way between its centre and the innermost wheel-cases. The object of hanging these two pieces *not* by their centre of balance is that one end being longer, and therefore heavier, than the other, may cause the pieces to fall round by their own weight, as the firework makes its revolutions. To these two pieces coloured lights are attached at each end in such a position that they shall project horizontally at right angles with the pieces *B B*.

This will be seen clearly by reference to the drawing at *C C.* (fig. 77), which is intended to give you a side-view of the same piece. It must not be forgotten that the satisfactory performance of this firework depends mainly upon the exactness and true adjustment of the woodwork. Unless the revolving pieces are neatly hung, and the balance of the main framework is true, you must not expect success.

The coloured lights may be arranged as follows :—A green and a red light on one of the revolving pieces, and a purple and red on the other. These coloured lights are all to be connected together and with the mouths of the two extreme wheel-cases by quick-match. It will be obvious, then, that the coloured lights must be so prepared as to last during the combustion of the three driving cases.

The drawing at (fig. 78) represents a rather better position for the wheel-cases than that given at (fig. 76).

The diagram (fig. 79) represents a wheel frame, to which are attached at *f f f* coloured lights. The position there indicated is a very good one for coloured lights when required for wheels of any such make as that in the drawing. You must not forget that they are all to be placed at *different distances from the centre of the wheel.* They may, of course, be made to play their part at any period of the wheel's revolution. The coloured lights, for whose manufacture I have given directions above, are very valuable auxiliaries in nearly all exhibition pieces, and that we shall have occasion to call them in frequently to our aid as our practical pyrotechny becomes more advanced, and our enthusiasm in the art leads us to search for new combinations and effects.

TOURBILLONS—PLAIN AND BRILLIANT.

51. The tourbillon is a species of firework very ingeniously contrived to represent a spiral column of fire. Its performance

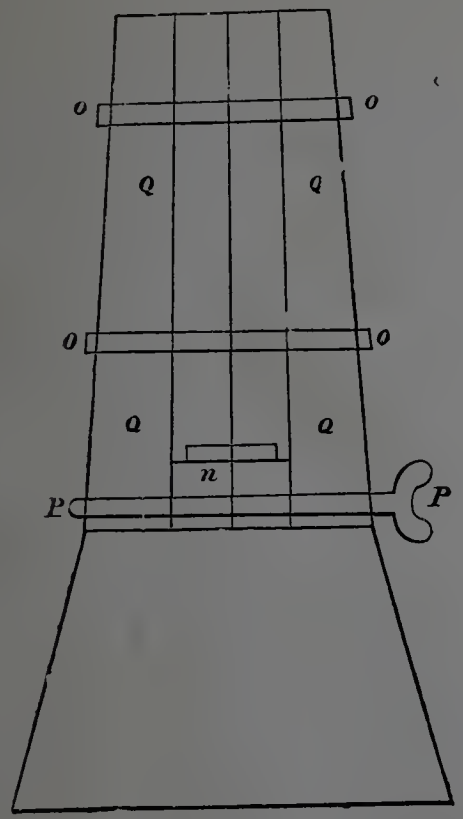


Fig. 83.

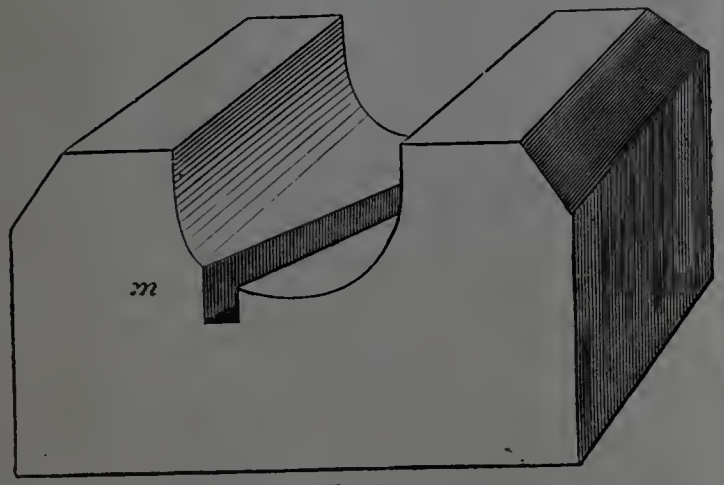


Fig. 82.

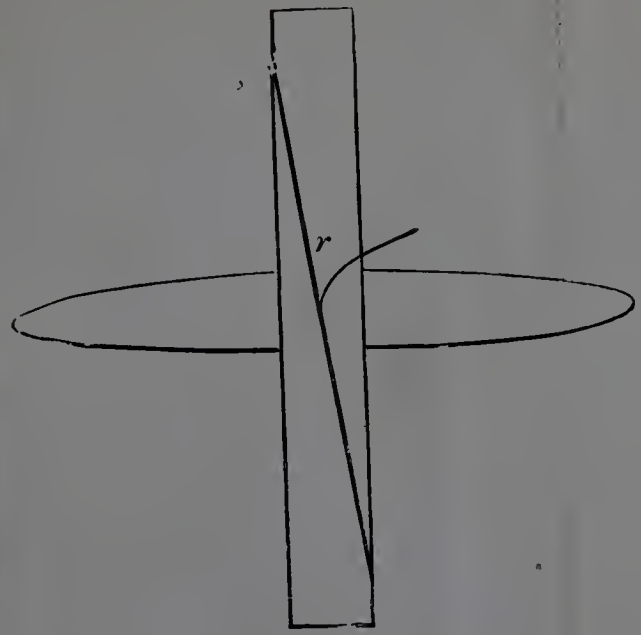


Fig. 84.

Fig. 85.

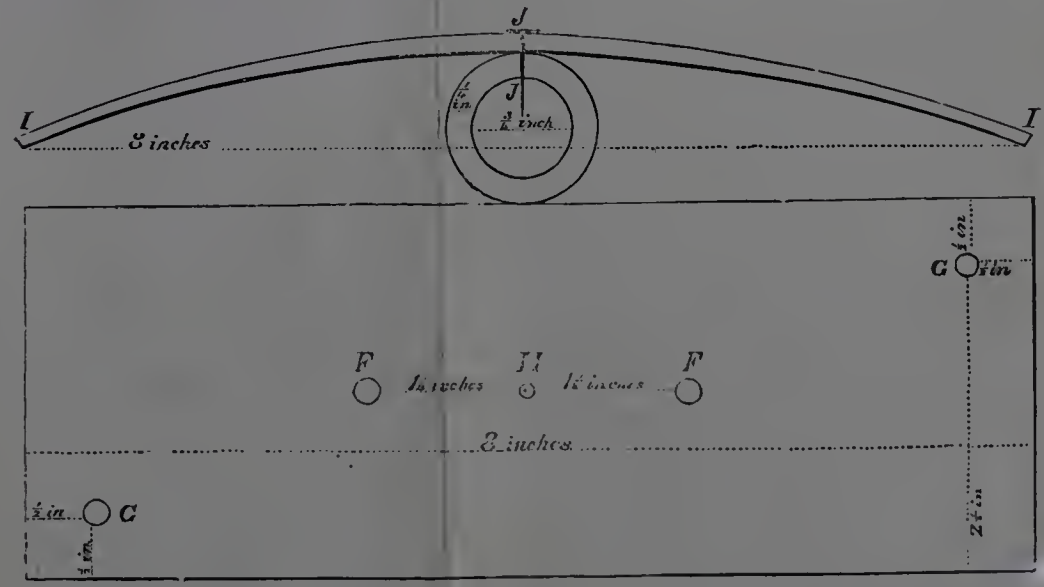


Fig. 86.

Fig. 82.—Block to receive the tourbillon while it is being bored. *m*—Groove in it to receive the quick-match. Fig. 83.—Block, with settle (*n*) over which tourbillons are rammed. *Q Q Q Q*—Wooden cylinder to enclose tourbillon case. *O O O O*—Iron rings to tighten cylinder. *P P*—Pin to pass through cylinder, and settle to connect them. Fig. 84.—Tourbillon complete, with stick attached. Fig. 85.—Revolving cradle from which tourbillons are fired. *s*—Iron spike, with tubular top, in which the cradle revolves. Fig. 86.—Metal tourbillon scale.

is of short duration, but while it lasts it produces a very striking effect, and is, moreover, entirely different from any other pyrotechnic piece.

The preparation of tourbillons requires a considerable degree of nicety and precision, for unless the several proportions of the piece be accurately preserved, the true and intended effect will certainly be lost, and the operator not merely lose a feature, but a very beautiful feature, in his exhibition.

Since, then, it is utterly impossible to prepare successful tourbillons by careless manipulation, and to hurry over any part of their manufacture without some deterioration to their performance, I must beg that my readers will carefully follow my directions in every particular. They will then be able to make these tourbillons as successfully as I do. But if they prefer to work out some principle of their own, they must not hold me responsible for its results.

For the benefit of those of my readers who may know little or nothing of what a tourbillon is, I will first endeavour to explain the principle upon which it is constructed, and then give in detail the various operations necessary for its completion.

A tourbillon consists of a stout case filled with a strong sparkling composition, and closed very tightly at both ends. In this case are bored four holes, at which the fire is to find vent. Two of these holes are made underneath the case; from these the fire issues in a downward direction, and gives the piece the power of ascending perpendicularly. The other two holes are made in opposite sides of the case near each end; the fire issuing from these causes the case to revolve in a horizontal direction while it is ascending.

Now, it will be obvious that to gain an exact counterbalancing of these two forces considerable care and precision will

be necessary. In order to make my directions as clear as possible, I intend to speak only of one size of tourbillon. You may make them of any size, from the 1-oz. up to the ½-lb. size, if you please; but you will find it by far the most *economical* and *certain* plan to keep to one effective size, and thus avoid all confusion and expense arising from the multiplication of tools and measurements.

We must first of all know how to make the cases. These are to be *of the quarter-pound size*. You will derive little advantage from adopting a larger size than this, and you will find smaller sizes unworthy of such an exhibition as I trust you will be able to make by following my directions in these papers.

From each sheet of your 70-lb. brown paper you will only be able to cut two strips of sufficient width and length to make the ¼-lb. tourbillon cases. These two strips are represented at *A* and *B* in the annexed diagram (fig. 80). *These strips must be eight inches wide.* Your sheets of paper measure about twenty-two inches on their short side; so that if *A* and *B* are eight inches wide, the remaining strip *C* will be only *six* inches wide, and useless, therefore, for tourbillon cases of our present size. But these spare strips are sure to prove useful for some purposes, and so no waste will be incurred.

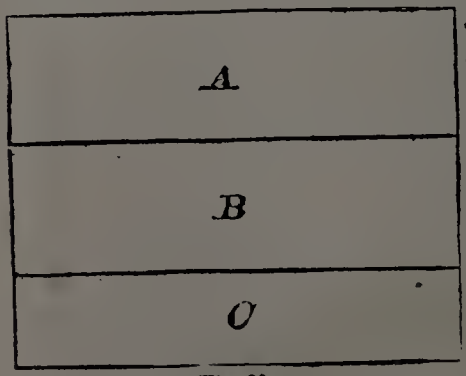


Fig. 80.

The imperial board for these cases must be cut as in the adjoining illustration. Each sheet of board will provide four strips of a size proper for our purpose, each of which will be eight inches wide and fourteen inches long. Those marked

a b c d are intended to represent the pieces to be used (fig. 81). Those marked *e e* should be kept with the spare strip marked *C* in fig. 80, and will make you a good ¼-lb. case for Chinese fire.

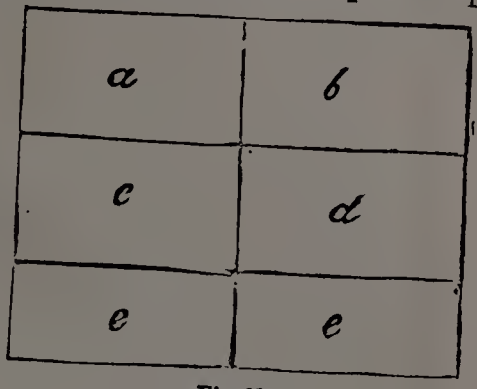


Fig. 81.

I will now suppose you to have divided your paper according to the above directions. In the next place you must paste both paper and board all over thoroughly. Brush some paste upon your ¼-lb former (the one used for making rocket cases, which is three quarters of an inch in diameter), and then roll on your paper and board in the manner described at p. 77. Especial care must be taken that the innermost end of the strip of paper (that which lies next to the former) is so thoroughly saturated with paste that it cannot become separated or loose. If this precaution be not taken, some of the composition will, in the process of filling, drift behind it —will form a quick-match, as it were, inside your case, and will infallibly cause the tourbillon over which you have otherwise taken so much pains to vanish in a neat sharp report, and you will discover to your annoyance that in the place of a tourbillon you have only made an inferior kind of marroon.

Well, your cases are now made, and are eight inches in length, and three-quarters of an inch in their bore. Their external diameter will be found to be about one inch and an eighth.

We must next speak of the composition proper for filling tourbillons. For this purpose I employ the following formulæ, which I think wil be found to answer well :—

No. 1.

FOR PLAIN TOURBILLONS.

Nitre	8 parts.
Meal-powder	16 „
Sulphur	4 „
Charcoal	4 „

The charcoal that I use in making up this formula is the same that I recommended for rocket purposes—that is, it should be partly fine and partly coarse. If the above composition be found too strong, more charcoal may be added until the desired strength be gained.

No. 2.

FOR BRILLIANT TOURBILLONS.

Meal-powder	16 parts.
Nitre	8 „
Sulphur	3 to 4 „
Charcoal (fine)	3 „
Steel filings	6 „

The effect produced by this composition is very good indeed, and in my hands leaves nothing to be desired. It is advisable not to fill the cases with composition No. 2 longer than necessary before use, as the steel is sure to become corroded to some extent, and then much of the brilliancy of the sparks is lost.

Some pyrotechnists use *iron borings* instead of steel filings for tourbillons. I cannot say that I have ever succeeded well with them. Iron particles will not work well in rapidly-revolving pieces, as far as my experience goes. They seem to me to become chilled too soon by their motion through the air, and produce hardly any scintillation. I, therefore, always use steel filings for all fireworks which are intended to

revolve, and employ iron only in those that are stationary. Now, having prepared your composition, you will be ready to ram it into your cases. For this purpose you will require a simple piece of apparatus, which Mr. Newman will make for you at a small cost. You will find a drawing of it on my page of illustrations (fig. 83). It consists of a block of wood provided with a "settle," on which one end of the tourbillon case is placed, and over which the composition is rammed. Then there is a wooden mould capable of inclosing the case and supporting it tightly and firmly while the operation of ramming is being performed. This mould consists of a hollow cylinder of wood pierced throughout, and of such a size in its bore as will just admit the tourbillon case. The mould is divided longitudinally in halves, and these halves are kept together by means of iron rings, which encircle the whole. You will find a full description given with the drawing.

In order to fill the cases, squeeze one end of one of them over the projecting piece at the top of the settle. Then fit on the two halves of the cylindrical mould, and drive down the iron rings until they are tight. The exterior of the cylinder is made to *taper*, in order that the rings may always fit tightly over it. And, lastly, put in the pin which secures the cylinder to the block and settle. You will now require a straight wooden drift, eight inches long (independently of its handle), and nearly three-quarters of an inch in diameter—one, in fact, that will pass *easily* into your tourbillon case. The tools you have already—viz., a scoop for the composition, a mallet, and the short *solid* drift which you used for driving in the clay over the composition in your quarter-pound rockets. First put into your tourbillon case as much clay as will, when rammed very hard, occupy *three-eighths of an inch in the length of the case.* The settle projects into the case

about one-eighth of an inch, and thus half-an-inch at each end of the case is left for the purpose of insuring a very firm ending, which cannot be blown out by the combustion of the composition.

When the clay has been rammed in as tightly as possible, drive in the composition, a ladleful at a time, as uniformly as you can, until you have only half-an-inch at the upper end of the case unoccupied by it. Into this vacant space drive the same quantity of clay that you put into the lower end, and be sure that it is rammed in very firmly indeed.

The ramming of your tourbillon is now completed, but the most important part of its manufacture has yet to come. Open your penknife, and lay its blade on the table, back downwards and edge upwards. Place your filled tourbillon case across the edge of the knife, and *find the exact central point at which it balances on it, and mark that point by making a hole there with a small bradawl.* Now, having found the centre of its balance, you have next to mark the places at which the holes are to be made, and by far the best way to save yourself trouble in this respect, and to insure the proper marking out of all your tourbillons, is to follow my plan, which I am now about to describe. At fig. 86 I have drawn out for you a shape which you must get copied exactly in tin or zinc sheet. This piece of sheet metal, *when bent into the form of a trough of such a size as to fit tightly round your tourbillon case*, will give you the true position of the holes. In using it you will have to put the filled tourbillon case into it, and make pencil marks through the holes that correspond to those drawn in my sketch, and you will then have got over the entire difficulty. In the middle of the scale which I have drawn is one small hole marked *H. This hole is to come exactly over the mark which you made with your bradawl at the balancing point*, and if this be done all the rest must come right.

Having thus marked the position of the holes, the next thing is to bore them. They should be as nearly as possible three-sixteenths of an inch in size. I use a large bradawl for boring the holes, and it is better to drive it into the case with a mallet than to work it in with the hand. It must not be driven in farther than necessary, the object being merely to make a clear hole through the case, and not to disturb the composition. If you drive in the bradawl with your mallet you will require a small block of wood with a groove cut in it, in which you can lay the case while making the holes. I have given you a sketch of such a block at fig. 82. If it is two inches square or rather more it will be quite large enough. You will find the block very useful afterwards in attaching the stick to the tourbillon.

The plan that I have given for the *tin or zinc tourbillon scale,* as I shall call it, is drawn out *quarter size,* and the dimensions, marked, so that no tinman can have any difficulty in copying it accurately. Your tourbillon case is 8 inches in length. Half-an-inch at each end is taken up by the clay endings, so that you have seven inches of composition in the case. The two extreme holes, *which are on opposite sides of the case,* are made at the ends of the composition. The fire issuing from these gives the tourbillon a horizontal revolution round its centre of balance. The two inner holes, which are on the under side of the case, should be the same distance from one another that they are from the extreme holes. The fire issuing from these gives the tourbillon its ascending power.

But we have now to connect all these holes with quick-match, in order that the composition may take fire at all the four points simultaneously. To do this, begin at one of the under holes (those marked *F* in the scale), and press into it the end of a piece of *uncased* quick-match, taking care that

the match reaches the composition. Then carry the match on to the nearest *side hole, and press it into it.* Then carry on the quick-match *over the upper side of the tourbillon* to the side hole at the other end of the case, and press it in there; and, lastly, carry it on to the remaining under hole, and press it into it.

Having completed this operation, cut some strips of thin paper, about an inch wide, paste them well all over, and cover the quick-match with them, holes and all. A very little practice will enable you to adapt this pasted paper very neatly.

The tourbillon, if now ignited, will be sure to go somewhere, but probably not in the direction which we should like it to take. In order to regulate its flight we must do as we did with the rockets, adjust a stick to it, which shall have the effect of keeping its under side downwards, and so of compelling it to move upwards perpendicularly, if at all.

This stick is usually made of a curved shape in the manne represented at *I I*, in fig. 86. Those that I use I get from Mr. Darby; they are eight inches long, about an eighth of an inch thick, and are made of beech. There is a small hole in their centre through which a *flat*-headed nail is driven into the tourbillon at its balance point, which you marked with your bradawl. The stick must, of course, lie at right angles with the case in the manner represented at fig. 84. It is a very good plan to put a drop or two of glue at the point where the stick touches the case, as it will then be prevented from shifting its position.

In driving the nail through the stick into the tourbillon, make use of the block represented at fig. 82, having previously cut at the bottom of its rounded groove another small groove diagonally, so that when the tourbillon is lying upside down in the large groove, for the purpose of having the nail

driven into it, the quick-match that extends across it may lie in the smaller groove, and may not be injured by being crushed, as would otherwise be the case.

The nails used should be about three-quarters of an inch long, and should have a smooth, flat head.

To fire the tourbillon, place it stick downwards on a level board, and see that it spins easily and freely on the head of the nail. Then with a portfire burn through the quick-match *in the middle on the upper side*. The tourbillon will make a few revolutions on the board before it begins to rise.

I have known several tourbillons fail, when I had reason to believe that there was nothing faulty in their make. They all behaved in the same unaccountable manner, jumping off the board and falling bottom upwards upon the ground. Of course, after this freak they could not right themselves. They appeared to sink into a kind of blustering, sulky fit, and when exhausted went out. Some time elapsed before I could assign any satisfactory cause for this remarkable behaviour, but at last I began to suspect the board on which the tourbillons were placed to fire them. It occurred to me that there was not room enough for the rush of fire from the under holes between the tourbillon and the board, that as soon as the fire had been conveyed to these under holes the force generated then and there was sufficient to throw the tourbillon over on its back, and thus effectually to prevent any further performance. Now this was by no means satisfactory, for if there is any single firework which requires care, exactness, and attention in its preparation, it is the tourbillon. I have often felt that I would much rather have a rocket than a tourbillon, for in the first place the latter takes much longer to make, and one feels that one should have some remuneration for one's trouble; and in the next place a good tourbillon, though it is a species of firework not by any means

so necessary to an exhibition as the rocket, is still one capable of producing a very unique and grand effect. I began to suspect that the board was the cause of my failure, and after a little consideration I came to the conclusions here enumerated:—

1st. That a board of proper size, shape, and level was a thing not always to be found when one wanted it, particularly if away from home.

2nd. That it was a very lumbering piece of luggage to carry with one when about to take an exhibition to a distance.

3rd. That, if warped by damp, or put out of its level in any way, it would be rather worse than useless.

4th. That something better might be contrived.

Whether I was right in blaming the poor board I do not know; but one thing is certain—that I have never, since the adoption of my new plan, had any failures at all with tourbillons.

I wanted something from which to fire the tourbillon which would leave it no excuse for turning on its back, which would be small and portable, and always ready for use.

I first made a brass cross of the shape and size indicated in fig. 87. In the ends of the arms I drilled holes, into which I soldered pieces of stout brass wire about two inches and a-half long. Thus a sort of cradle was formed like that which is represented at fig. 85 in the plate. The next thing to be done was to enable the cradle to revolve very easily. To do this I soldered on to the centre of the under side of the cross a piece of brass rod of the size generally used for stair-rods. This piece was about six inches in length, and was filed at its lower extremity to a point on which it might revolve. I thus had made a thing like that in fig. 88. Now all that I had to do was to get a piece of glass tubing, into which my piece of rod at *a a* would fit easily, and in which it would turn freely. This I did,

and procured also a piece of iron rod half-an-inch in diameter and about eighteen inches long. I had this forged into a kind of spike point at its lower end, and filed at its other end, to pass about an inch into the brass tube, and then I had the tube and iron spike soldered together. This iron spike I press into the ground, taking care that it is upright, and then drop the brass rod which is soldered to the cradle into the brass tube at the top of the spike. The cradle will be found to revolve freely. In it I lay the tourbillon, with its stick downwards. When it is fired the holes at its *sides* are first ignited, and so its *horizontal* revolutions begin before any ascending power is given to it. The cradle of course revolves with it, and, if properly made, can offer no obstruction of any kind to its free play. But as soon as the fire is communicated to the *lower* holes, the force there developed will lift the tourbillon out of the cradle, and will send it on its upward flight.

My description of this little piece of apparatus may, perhaps, incline my readers to imagine that its manufacture is difficult. I can only assure them that it is not so, and that, if they will only give it a trial, they will be convinced of the advantages which it possesses over the old plan of the board. Probably some modification of its principle will occur to you which may render it still more easy to be made. The means at your own command are, after all, the best referees as to which is the shortest and readiest method of carrying out any plan. I have given you the method by which I obviated the difficulty that met me. I need only add that if you use the board I hope that your tourbillons will not disappoint you as mine did me.

Many persons make *six* holes in their tourbillons—four on the under side, and one at each end or opposite side. For my own part, I never could see the advantage of this plan. I

have tried it and succeeded with it, but the effect has been always to convince me more firmly of the superiority of the four-hole system. I know one or two very successful pyrotechnists whose experiments have led them to the same conclusion.

It is possible to ram tourbillons without a cylindrical mould, but it is neither advisable nor convenient. The cases require some very substantial support while they are being filled, for the composition cannot easily be driven too hard. The cylindrical mould cannot be an expensive apparatus if made as I have suggested. Mr. Newman has such facilities for boring blocks of wood and turning them, that I strongly recommend you to get him to make you one, as it will considerably lighten the trouble of preparing tourbillons, besides giving them, when prepared, a much better chance of success.

I beg here to give my readers the size of 70lb. paper and imperial board, that there may be no difficulty in knowing what to purchase. The sheets of 70lb. brown paper and imperial board are of precisely the same size, which is $22\frac{1}{2} \times 29$ inches.

I must conclude the subject of tourbillons with one hint. The person who fires a tourbillon with a portfire will generally fail to get a good view of its performance. The plan that I commonly adopt is to cut an inch of quick-match and twist some touch paper round one end of it, and lay the other end next to the match on the tourbillon at the point *r* in fig. 84, pasting a piece of thin paper over it to secure it, and leaving its other end free, with the touch-paper round it.

COLOURED FIRES.

52. *Coloured fires*, such as are employed for illuminating gardens, shrubberies, avenues, buildings, &c., will now occupy our attention.

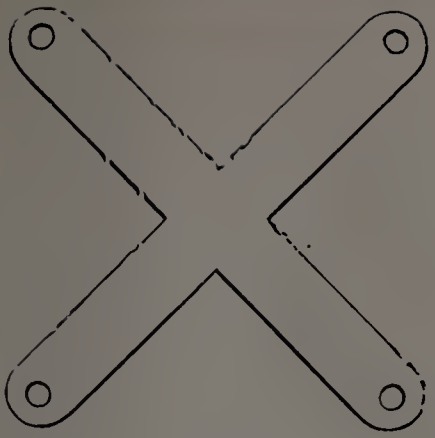


Fig. 87.

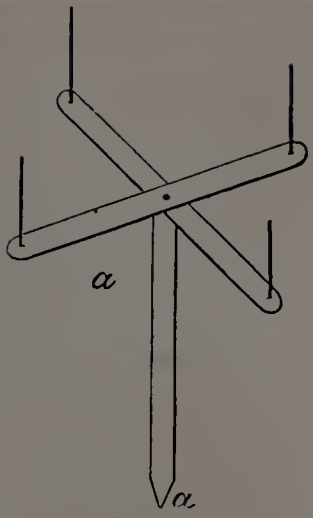


Fig. 88.

Fig. 90.

Fig. 91.

Fig. 90—Former for Coloured Fire Cases.
Fig. 91—Iron Fork to support Coloured Fires while burning.

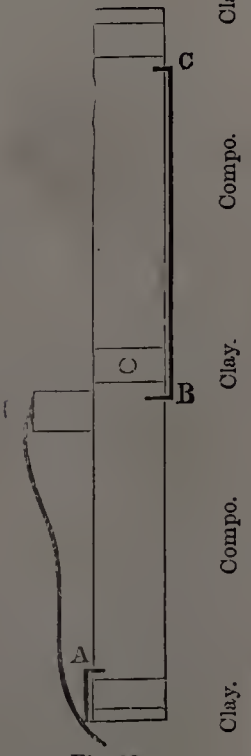


Fig. 93.

This species of firework is of very simple construction, and requires only an ordinary amount of care in order to insure its success. And it is very fortunate that so necessary an item in the programme of a pyrotechnic display is one which can be relied upon for producing so beautiful and surprising an effect. I have known spectators more pleased with the coloured fires in an exhibition than with any other of its features; and I am convinced, that by a well-contrived introduction and arrangement of them, results may be produced at least as effective and satisfactory as by any combination of a much more elaborate character.

But before entering upon the description of their manufacture, it will be necessary for me to remind you of some information that I have already given in the portion devoted to coloured stars, in order that you may be induced not to prepare your colours for an exhibition until you know *what you are going to prepare them for*—that is, what sort of a place they are required to light up.

What I have before said under the head of Coloured *Stars* with regard to the illuminating or reflective properties of this or that composition, must more than ever be borne in mind in the matter of coloured *fires*. There are two kinds of fires used in pyrotechny—one burning with a considerable depth and richness of tint, but possessing a very moderate illuminating power, the other having great brilliancy and reflective power, but not the same depth of colour. Now with this plain distinction before us, there will be no difficulty in selecting such composition as will produce the desired effect. You have simply to make up your mind beforehand whether you require a colour of considerable intensity, *which you may gaze at while it burns*, or one whose beauty will be seen to advantage, *not in itself*, but in its reflection upon those objects which are within reach of its illumination.

The formulas which I shall give will be characterised as "reflective," or "intense in colour," and if they are only made up with pure, dry, and fine ingredients, will, I am sure, give as good results as need be desired.

In the first place the preparation of the cases is to be considered. With regard to these it must be remembered that they are required *to burn with the composition*, and must not be made too thick or hard on that account. The thicker they are, the more will their consumption interfere with the burning of, and impair the colour produced by, the composition. A sheet of 60lb. or 70lb. brown paper cut up into nine strips in the manner represented at fig. 89 will furnish you some very good cases for the purpose. Each of these strips will be a little over three inches in width, which, in my opinion, is quite sufficient. The former for these cases is made of wood, and should be from an inch and a half to an inch and three quarters in diameter, and about four inches long, irrespectively of its handle. The drift for filling the cases may be of the same length, and *one-sixteenth* of *an inch smaller in diameter*, so as to admit of its passing easily in and out of the case.

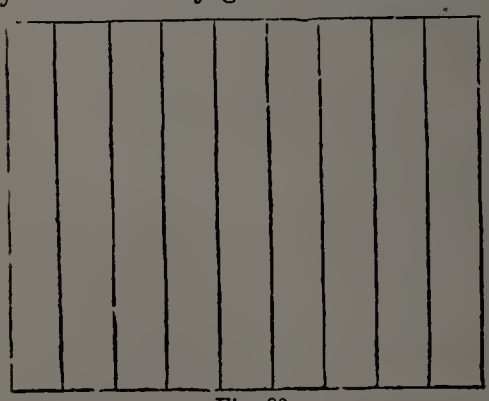


Fig. 89.

The difficulty that I have always experienced with regard to these cases has been this—they must be made of a certain thickness, in order that they may not be broken during the process of ramming in the composition. This process is, I believe, indispensable. At all events, I find it so, for *if the composition be only pressed in loosely, and not rammed, it will*

fall to the ground in burning lumps, instead of burning slowly and evenly in and with its case; and if the cases be made unnecessarily thick, either the composition will not burn freely enough, or its colour will be impaired (and this will be particularly the case with regard to *green* fires), or, what is more probable still, both these calamities will happen at once, and render your production doubly ineffective.

Now my plan for obviating the difficulty has been to increase the *diameter* of the cases, and thereby to gain a greater body of composition in proportion to their *thickness.* This plan I have found to answer very well, and so I can conscientiously recommend it to you.

Take, then, one of the strips of paper, cut as recommended above, and, pasting it all over on one side, roll it evenly round your former, having previously brushed a little paste over the former to prevent the paper sticking to it. Having rolled the strip up evenly and smoothly, take it off from the former, and set it by to dry. It will readily be percived that these cases are among the easiest to make.

And now we may pass on to the important subject of the compositions with which these cases are to be filled.

The first of these is known as the—

COMMON BENGAL LIGHT.

53. It has a bluish-white colour, and is called by some pyrotechnists "Artificial Moonlight." Its composition is—

No. 1.

Nitre	12 parts.
Sulphur	4 „
Antimony	1 part.

Orpiment or realgar may be substituted for the antimony, in which case there will be less smoke.

The above is the commonest sort of Bengal light. It gives a pretty effect, but has no great illuminating power.

64. WHITE FIRE.

WHITE FIRE.

No. 2.

Nitre	32 parts.
Sulphur	8 „
Regulus of antimony	12 „
Red lead	11 „

This is a French composition, introduced by Chertier, and is remarkable for its whiteness. It will be found a very useful composition, possessing a fair reflective power.

WHITE FIRE.

No. 3.

Nitre	24 parts.
Sulphur	7 „
Realgar	2 to 3 „
Antimony	1 part.

This I always find the most serviceable composition on the whole. It does not possess the intense whiteness of No. 2, but has a slight tint of blue ; and this difference alone would gain it the preference in my judgment. But it has also a greater illuminating power, and is decidedly the best composition that I have yet been able to find.

The red lead recommended in composition No. 2 can be purchased in fine powder, ready for use, at any painter's or chemist's shop.

YELLOW FIRE.

55. We may now proceed to the formula for—

YELLOW FIRE.

No. 4.

Nitrate of baryta	36 parts.
Oxalate of soda	6 „
Sulphur	3 „
Shellac	5 „

This composition produces a good colour and has a moderate reflective power. Its principal merit lies in the fact that it will keep good for any length of time after it is mixed, and can be made with samples of nitrate of baryta which will not produce a good green.

YELLOW FIRE.

No. 5.

Nitrate of soda	48 parts.
Sulphur	16 „
Antimony	4 „
Charcoal (fine)	1 part.

This is decidedly the best formula for yellow fires, as far as effect is concerned. But the nitrate of soda is so highly deliquescent that the composition must on no account be made up longer before use than is absolutely necessary. Yellow fires are not much used in pyrotechnic exhibitions. I suppose this is to be accounted for by the extraordinary power that they possess of giving to all objects, especially the human face, a ghastly and death-like appearance, anything but agreeable to behold. I have no doubt, however, that some of my younger readers, knowing this, will set a higher value upon the formulas for yellow fire, for the fun of showing off the spectators of their exhibitions to the greatest possible disad-

vantage. Especial notice should be taken of the complete annihilation of colour in flowers, dresses, &c., by this yellow light. The effect is, of course, very similar to that produced by the burning of spirits of wine or naptha holding salt in solution. This latter is known as the *monochromatic light;* that is, a light in which only one of the colours of the spectrum is shown.

Although I do not remember ever having seen a yellow fire used in any large exhibition of fireworks, I have given the above formulas in order to render my paper upon the subject as complete as possible.

The next colour with which we shall deal will be the

GREEN FIRE.

56. For this colour I shall give three formulas, all of which I have found good, notwithstanding the universally acknowledged difficulty of obtaining a real green colour. This difficulty has arisen, I believe, solely from the imperfections and impurities in the nitrate of baryta which finds its way into the market. This salt should be prepared from the sulphate of baryta, *and not from the carbonate;* and I think I am right in stating that it is far more generally prepared from the carbonate than from the sulphate. When this is the case you either get a very decent *yellow* colour from the sample, or you get a salt which burns about as green as a very bad specimen of nitre will burn. My readers will readily understand that nitre ought not to be so green as to admit of this.

And now, before giving the formulas, it only remains for me to say that if you have but a really good sample of *dry* nitrate of baryta *in fine powder*, you ought to be able to make from the following receipts a green fire which will answer any purpose:—

GREEN FIRE.

No. 6.

Nitrate of baryta	45 parts.
Chlorate of potash . . .	10 „
Sulphur	10 „
Antimony (sulphide) . . .	1 part.

The above formula gives a pure but pale green. It has a most intense illuminating power, and for this cause is very valuable. The addition of a little nitrate of baryta will render the composition more intense in colour, but will detract from its rapidity of combustion, and therefore from its illuminative power.

No. 7.

Nitrate of baryta	77 parts.
Chlorate of potash . . .	5 „
Sulphur	12 „
Charcoal	2 „
Orpiment or realgar . . .	2 „
Shellac	2 „

Composition No. 7 is a very old one, slightly altered to make it burn more freely. It gives a more intensely green colour than No. 6, but has not the same advantage with regard to its illuminative properties. It is, however, a very serviceable and inexpensive receipt to employ.

We now come to the best of all the formulas for green fire that I have been able to meet with, and one which has thoroughly satisfied me. It is almost the same as that recommended by Chertier, the difference consisting in a slight decrease in the quantity of calomel, which enables the composition to burn rather more freely and adds to its reflective power. I have seen a real emerald green produced by this composition when good nitrate of baryta has been used, but in this, as in the case of all other green fires, if you do not suc-

ceed you may generally fasten your suspicions upon the nitrate of baryta.

No. 8.

Nitrate of baryta	40 parts.
Chlorate of potash	4 „
Sulphur	8 „
Calomel	8 „
Charcoal (fine)	2 „
Shellac	1 part.

I do not think that any better formula than this can be needed. It carries with it a better combination of intensity of colour with intensity of illuminating power than any coloured fire composition that I am acquainted with.

PURPLE FIRE.

57. I have next a formula to offer which I think has considerable merits of its own. It produces a purple colour of a very pleasing tint, and has also very considerable illuminating power. I have never seen a colour of this kind employed in any pyrotechnic exhibition, but I believe it to be an effective composition, and one certainly that will make a change from the ordinary routine of white, green, and red. I shall dignify it by the title of—

PURPLE FIRE.

No. 9.

Nitre	48 parts.
Sulphide of copper	12 „
Sulphur	12 „
Calomel	6 „
Arsenic	6 „
Nitrate of strontia	6 „
Chlorate of potash	4 „
Shellac	4 „
Charcoal (fine)	1 part.

I trust that my readers will not be alarmed at the number of ingredients in the above formula. I can only promise them that the colour produced is an extraordinary one, and cannot be produced by ordinary means. You will observe that I have recommended 12 parts of sulphide of copper. This must be the *fused* sulphide. Or you may substitute for it equal parts of Chertier's copper and sulphide of copper, or equal parts of Chertier's, or of sulphide of copper and fine black oxide of copper. The *arsenic* employed in the formula may be either orpiment or realgar, but by far the best preparation of arsenic for this purpose is the *finely-powdered metallic arsenic*. Formula No. 9 is one of my own introduction. It possesses the advantages of being perfectly safe, deep-tinted, and decidedly illuminative. But I do not pretend to say that it can ever be admired to the same extent with the red and the green fires. These latter will always take the precedence, for their effect at night is so thoroughly theatrical and surprising that no other colour, however beautiful or extraordinary, can hope to supersede them. I was once asked by a lady to make a *brown-coloured* flame. The idea was so rich in theory that I never attempted to dissolve its charm by any failures in experimental practice. But had I succeeded to the utmost with this brown fire, no illuminating properties could ever have been obtained. One might as well have expected a good effect from a *black star* or a *neutral tinted sun*.

RED FIRE.

58. We come now to the most telling colour of all—the red, or crimson as it is usually called. In the preparation of the *green* fires the *purity* of the nitrate of baryta is the most important consideration In that of the red fires the *dryness* of the strontia is the main point. This is most especially to

be borne in mind, as success or failure depends upon it. A really good red-coloured fire is often the making of an exhibition or its redeeming point, but in any case it is a most important feature, and on that account is worth the expenditure of any trouble on its preparation.

I shall give several formulas for red fires, each having its own characteristic properties. You will have but to determine the particular description of fire that is necessary, and I think you will find all that you need among the following compositions :—

RED FIRE.

No. 10.

Nitrate of strontia . . .	20 parts.
Chlorate of potash . . .	3 „
Sulphur	5 „
Antimony	2 „
Charcoal (fine)	1 part.

This formula gives rather a deep rose-coloured flame, and has a most intense illuminating power. But the composition is one on which the non-dryness of the nitrate of strontia has the most disastrous effects. It is, when properly prepared, a very useful composition for illuminating buildings, &c., &c.

The next is a slower composition, having decidedly more intensity of colour. It is a remarkably good composition, having considerable depth of tint, and a very fair amount of reflective power. Its proportions are these :—

No. 11.

Nitrate of strontia . . .	64 parts.
Chlorate of potash . . .	4 „
Charcoal (fine)	5 „
Sulphur	24 „

The next formula is one of very slow combustion, but of

the greatest depth of colour. It has but a small illuminating power, and can therefore be employed only for certain purposes.

No. 12.

Nitrate of strontia	48 parts.
Chlorate of potash	4 „
Sulphur	12 „
Calomel	8 „
Chertier's copper	2 „
Charcoal (fine)	1 part.

This composition, burns so slowly that if it be very much compressed, or its case be at all thick, much of its effect is lost. I should therefore recommend that it be laid in a heap upon a tile in order to be fired. Its beauty will then be seen to the greatest advantage.

The following composition for red fire is the one which I have always found the most generally useful:—

No 13.

Nitrate of strontia	70 parts.
Chlorate of potash	6 „
Sulphur	24 „
Charcoal (fine)	2 „
Shellac	2 „

This composition, when employed in a case $1\frac{3}{4}$ inch in diameter, produces a magnificent effect, and is at the same time a very economical composition to make up. Its combustion does not appear rapid, and yet there seems to be no lack of illuminating power combined with intensity of colour. It is, of all the compositions which I give, the one best adapted for the use of young aspiring pyrotechnists, as very certain in its results, very inexpensive, and very easy to prepare.

Thus we are brought to the close of our list of compositions for Coloured Bengal Fires. I trust that this list will be found to contain all that you require, and contain it, too, in variety and abundance.

But we have still to consider how these compositions are to be encased and fired.

COLOURED FIRES (To Encase).

59. The cases, made as directed above, I will now suppose to be dry and ready for use. Your drift, with which the composition is to be compressed into the cases, is one-sixteenth of an inch smaller in diameter than your former. It will therefore pass easily within the cases which were made upon "the former." Now cut some pieces of newspaper, or thin brown paper, into squares or circles about 3 inches in diameter. Place the flat end of your drift in the centre of these, and turn down the papers round its sides in the same way that papers or bladders are turned down over bottles or jars when these are to be capped or covered. Then insert the drift with the paper cap over it into one end of the coloured fire case and push it through to the other end. Now withdraw the drift, and leave the paper cap in the end of the coloured fire case. Next place the case upright upon your driving-block with the end, thus filled up, downwards, and put into it as much powdered clay as will, when driven, occupy about half-an-inch in the end of the case. Drive this clay down firmly with a few blows of the mallet, taking care, however, not to rupture the case by exerting too great a force.

The case is now ready to be filled with composition. This operation is to be done as follows:—First put in enough of the composition to occupy about half-an-inch in the case, and ram this down with a few light blows of the mallet. Then put in another quantity, and ram that down in the same

way; and so on till the case is filled. I strongly recommend you not to put in more composition at a time than will ram down into the space of half-an-inch. You will find it easy to compress the whole of the composition equally and uniformly by attending to this simple piece of advice; and you will soon discover, if you do not already know, the advantage of uniform compression.

When you have charged the case as far as you can with the drift and mallet, that is, to about a quarter of an inch from the top of the case, press the mouth of the case into the composition (from which you were filling it) until the case becomes full up to the brim. Over the flat surface of composition thus left, paste a piece of touch-paper, or any thin paper, taking care not to paste that part of the paper which lies against the composition, but only that which is to stick to the sides of the case.

COLOURED FIRES (To Fire).

60. Your coloured fire is now complete and ready for firing. This is the usual and most convenient way of preparing colours for exhibitions. But for your own experiments you may place a small quantity of the composition to be tried upon a tile or brick, not spreading it about, but piling it into a pyramidal heap, to be lighted at the top. Many persons adopt this plan for exhibitions, but it is not good, because several of the best compositions burn too rapidly when unconfined by a case. I only beg that you will do me the justice to remember that the formulas which I have given above are intended to furnish compositions suitable for burning in such cases as I have described, and not, as a general rule, adapted for open and loose burning. My plan all along has been this—to find compositions of sufficient freedom of combustion to enable them to consume their case, to give a

powerful light, and not to burn out too rapidly. I think I have succeeded in gaining the first two of these qualities in the compositions themselves, and the third by compressing them closely in cases.

It is very much better to put into each case two different sorts or colours of fire, making the fire, for instance, change from white to red, or from green to purple. But if this be done, and more than one case is to be burning at a time, of course an especial regard must be had to the contrast of colour. You should never burn a yellow with a red fire, or a yellow with a white; green with red, yellow with purple, white with red make the best contrasts.

But, for my own part, I never burn two Bengal fires of different colours at once. If the fires have any illuminative power at all, they are pretty certain to neutralise one another's effect, and so give you a very poor and unsatisfactory return for your outlay. It is very true that red and green are *complementary* colours, as they are called, and look very well side by side, but the effect produced upon an object by illuminating it with a red and green light is anything but complementary to the object or to the coloured fires themselves. If you wish, however, to try the effect of the contrast, use compositions possessing the greatest depth of colour and the least reflective power; in this case the fires themselves will be complementary one to another, and their non-illuminative properties will effectually prevent any confusion of reflection. That what I have said above is true any one may discover by getting two pieces of stained glass, one of a rich red, the other of a rich green colour. Let these colours be thoroughly *transparent*, and if you place one before the other and attempt to look through them, you will find that you have a medium through which very little can be seen at all.

The cases of coloured fire, made as directed above, must

not be placed perpendicularly to be fired, but *horizontally.* The reason of this is very simple. While they are burning a sort of boiling lava is formed, which is the refuse of the combustion, and this will considerably clog the flame and rob it of much of its light if allowed to remain at the mouth of the case. Now if the cases be placed horizontally, this lava will fall away as it forms, and leave the fire to burn without impediment.

All that it is necessary to do to give the cases this horizontal position is to drive two long, stout nails into a post horizontally, about an inch and a half apart, and lay the case on these. Coloured fires should, as a general rule, be fired at a distance of about three or four feet from the ground.

But as one cannot always find nails of the proper sort for these purposes, especially when at a distance from one's own stores, I have sketched for you an iron which I always use, fig. 91, and which I am sure you will find convenient. It is made in the shape of a tuning-fork, with a screw at its handle; this screw is simply twisted into a gimlet-hole in a post, and is easily put up or removed.

I must not omit to say a few words with regard to the placing of coloured fires. This must depend mainly upon individual taste, but a few hints may not be out of place. I cannot help thinking that the best and most effective way of displaying coloured fires is *to conceal the fire itself, and let only its illumination or reflection be seen.* Let any of my readers keep his spectators at a distance of twenty or thirty yards from the coloured fire, and hold up a tray or piece of board in front of the fire, of such a size as will conceal only the fire itself. I think it will be generally admitted that the beauty of the piece is much enhanced by this simple contrivance, and if it be thought so, then it becomes a consideration whether it would not be better to use the most illuminative colours

always out of sight, in such a position that their effect only can be seen. For instance, if there be a large tree conveniently at hand, place your colour on that side of it which is away from the spectators, so that the trunk of the tree is between them and the coloured fire. This plan I have always found to give a most charming result.

But it must be remembered that anything but highly illuminative colours cannot be employed in this manner. You will of course find objectors to the plan mentioned above. There are many people who will tell you, "No, I like to see the light itself," as if gazing on the sun or moon, except for astronomical purposes, could ever give half the pleasure that the sight of a fine sunlit or moonlit landscape can impart.

What would a fairy scene in a pantomine be worth if you saw some of the green-room myrmidons, with a pot of beer in one hand and a lucifer-match in the other, lighting a heap of composition on a tile beside the stage, and then saw the composition burst into a smoky flame, but were prevented from seeing the effects of its colour?

This suggests to me another branch of my present subject, which some of my readers may consider an important one.

COLOURED FIRES FOR THEATRICAL PURPOSES.

61. In the event of private theatricals you may not, or your friends may not, like their drawing-room to be filled with a strong sulphurous smoke, which is pretty certain to hang about the drapery of the room and the dresses of the company for some unpleasantly long time. I shall therefore give you now two or three formulas for coloured fires which may be safely used in a room, and which contain no sulphur.

But first let me give you this caution, which it is most highly important that you should attend to :—

NEVER BURN ANY COLOURED FIRE COMPOSITION IN-DOORS, OR IN ANY INCLOSED SPACE, WHICH CONTAINS ORPIMENT, REALGAR, OR ANY PREPARATION OF ARSENIC AMONGST ITS INGREDIENTS. THE FUMES FROM SUCH COMPOSITIONS MUST BE VERY INJURIOUS. THEY CAN ONLY BE USED WITH SAFETY OUT OF DOORS.

COLOURED FIRES FOR THEATRICAL PURPOSES.

WHITE.

No. 14.

Chlorate of potash	12 parts.
Nitre	4 „
Sugar	4 „
Stearine	1 part.
Carbonate of baryta	1 „

This does not give a pure white light, for it is impossible to get a real white without sulphur, but when used to overpower theatrical lamplight, it is to all intents and purposes white.

YELLOW FIRE.

No. 15.

Chlorate of potash	6 parts.
Nitre	6 „
Oxalate of soda	5 „
Shellac	3 „

Nitrate of baryta may be substituted for nitre in the above formula with advantage, provided it be very dry and fine.

GREEN FIRE.

No. 16.

Chlorate of potash	2 parts.
Sugar	1 part.
Nitrate of baryta	1 „

This green colour is but faint in itself, but gives a very good reflection.

RED FIRE.

No. 17.

Nitrate of strontia . . .	4 parts.
Chlorate of potash . . .	1 part.
Shellac	1 „

These colours are for the most part very rapid in their combustion, and therefore may be used in cases if you please. But as coloured fires for theatrical purposes are only required to last a short time, the more brilliant they are during that time the better.

CHINESE FLYERS OR SAXONS.

62. I now treat of the manufacture of Chinese flyers, or Saxons, as they are called by professional pyrotechnists. But it will not be sufficient merely to speak of the manner in which they are made—we must follow them into some of those combinations in complex designs in which they fulfil a very striking part.

And first the object of the Chinese flyer is to produce a circle of white fire, unattended by any scintillating radii, which can be easily worked into large pyrotechnic designs, and which is at the same time easy of construction.

The Chinese flyer forms a very pretty little piece of itself when properly made, but its principal use is in combination. It is of two kinds, and these are known by the names of the "single" or "double" Saxon or flyer.

SINGLE SAXON FLYER.

63. First we will speak of the single Saxon. Its case should be eleven inches in length, and should be made round a "former" of the one-ounce size. In order to cut your

Fig. 94.

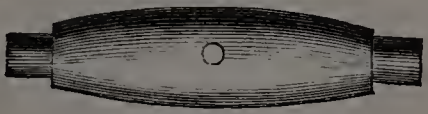


Fig. 95.

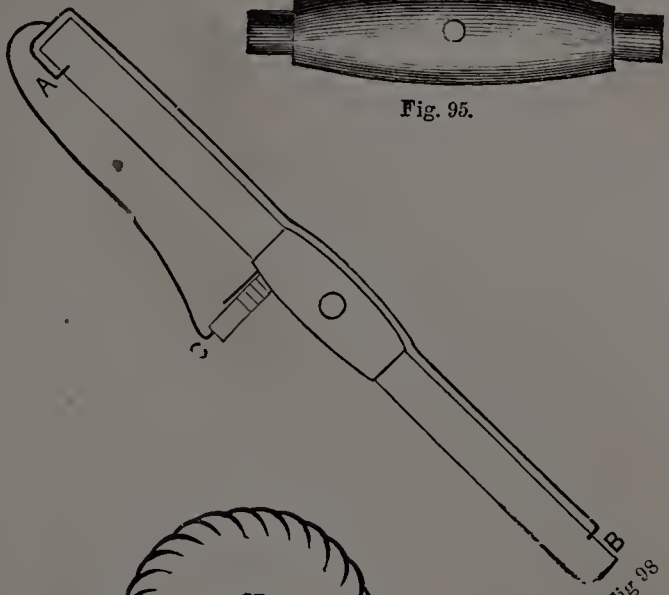


Fig 98

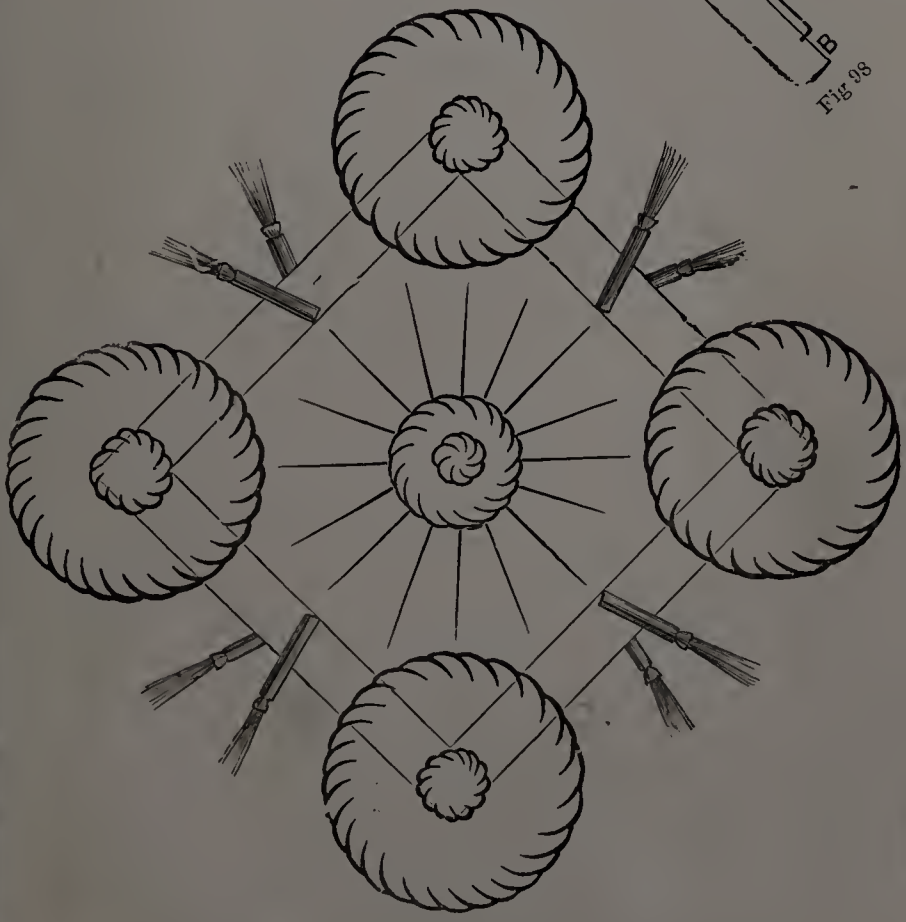


Fig. 99.

paper and board of a proper size for these cases, refer to the following woodcuts. Open a sheet of 60 lb. brown paper of the imperial size, and divide it in halves lengthwise. At fig. 92 it will be seen that each sheet of paper will give you two cases. If you use 70 lb. brown paper instead of that of the 60 lb. substance, you will hardly require any imperial board. But I think that the cases are better when made with a piece of the board used with the paper. Supposing, then, that you employ 60 lb. brown paper, cut your imperial board as shown at fig. 92a, that is, into eight equal pieces, one of which is to be used with each strip of paper.

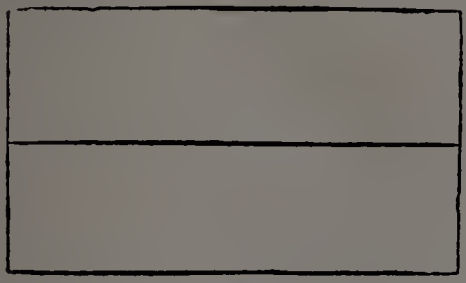


Fig. 92.

Fig. 92a.

Now paste your paper and board well all over, for you will require a hard, strong case. Then proceed to roll your paper round the former, folding it over in the manner described at par. 39. Then place upon the unfolded paper the piece of imperial board, and roll both up together into a close firm case. Your former should be moistened with paste, and particular care must be taken that the inner fold of the paper, that which lies next to the former, is well saturated with paste. This will effectually prevent its being separated afterwards when dry, and will obviate one cause of failure and explosions. I have before explained the necessity for attending to this piece of advice in speaking on tourbillons. The cases for these Chinese flyers are, in fact, very much like those

made for Roman Candles, but as they are to contain a very much stronger composition, must have so much additional care bestowed upon their preparation.

The next thing necessary is to know the principle upon which these Chinese flyers are made. A reference to fig. 93 will make this easily intelligible. The composition is rammed into the cases in two compartments, between which and at the extreme ends of which some dry powdered clay is driven in. The clay in the centre of the case is put there to form a solid substance, through which a hole can be bored to admit the spindle on which the case is to revolve. The clay at the extremities of the case is driven there to form a hard ending which is capable of resisting the force of the combustion of the composition. The intervening spaces between the ends and centre of clay are filled with composition.

The cases are filled over a settle proper for the purpose, of which a sketch is given at fig. 104. When the cases are dry, take one of them and place one of its ends over the projecting piece at the top of the settle. You will now require a long drift, rather less than half-an-inch in diameter, so that it will pass easily in and out of the case. It must, of course, be of a length not less than that of your case. I must suppose that you provided yourself with a ladle proper for filling the cases of brilliant fire, and the wheel-cases, of which I have treated. The same ladle will now come into use again. In case you have not such a ladle, buy or make yourself one in metal which will pass easily into cases of the one-ounce size. In this ladle take up as much powdered clay as will, when driven, occupy a quarter-of-an-inch in the length of the case. Drive it in firmly by means of your drift and mallet. Then put in the composition, for which the following are the formulas:—

COMPOSITION FOR SAXONS.

Meal-powder	16 parts
Nitre	8 „
Sulphur	6 „

Or,

Meal-powder	6 „
Nitre	3 to 4 „
Sulphur	2 „
Antimony	2 „

Of these two I prefer the former, but the latter is perhaps better when the flyers are to to be fired singly, as it produces a much greater halo of sparks.

Now drive in the selected composition, a ladleful at a time, giving from twelve to sixteen blows to each, until it rises to half-an-inch below the middle of the case. It is a good plan to mark cases, so that there shall be no possibility of mistake as to where this point is. Remember that you will require one inch of clay in the exact centre of the case, in the middle of which clay you will have afterwards to bore a hole. Upon the top of this clay ram in more composition until the case is filled to about three-eighths of an inch from the end. Upon this second composition drive in as much powdered clay as you drove in at the other end of the case, taking care that it is made very firm, and is not at all likely to be blown out by the combustion of the composition.

The next thing to be done is to bore the central hole through the clay. I do this generally with a bradawl first, and afterwards with a pin-bit or spoon-bit. The size of spindle which is best adapted for such fireworks as these is that which is three-sixteenths of an inch in diameter. I should therefore use a bradawl of about an eighth of an inch in diameter first, and then a pin-bit of the same size as the spindle to be em-

ployed. Care must be taken that the hole is not made unnecessarily large, and that it is bored at right angles with the length of the case.

Having accomplished this, you have in the next place to bore the holes from which the fire is to issue. These are to be made on opposite sides of the case at each end, and about half-an-inch from the ends of the case. I make these holes with a bradawl, beginning with a small one and finishing with one rather less than three-sixteenths of an inch in diameter. I believe the true size of the awl that I use to finish with is five thirty-seconds of an inch. I mention this because some considerable nicety is required with regard to the sizes of these holes, otherwise the Saxon will either burst or not have force enough. The compositions that I have given have reference to holes of the above size, and will not be found to succeed well with any other sized aperture. I bore these holes about half-way through the composition, and then nearly fill up the hole with some of the same composition, leaving room for the ends of the match to be pressed in. A very convenient instrument for filling up these holes after boring, also for filling up tourbillon holes and the necks of wheel or brilliant fire cases, is that represented at fig. 94, which consists of a piece of stout brass wire driven into a bradawl-handle, and having a flat end. This simple instrument will serve also to press in the ends of the quick-match which is to connect the extremities of the case.

At fig. 93 is represented the manner in which the quick-match is applied. A hole is bored at A. A piece of match is put into it and carried to the end of the case for the convenience of lighting the flyer. A piece of thin paper is pasted ove the match and round the end of the flyer to keep the match in its place, and to protect it from injury and from taking fire before its time. Another hole is made at B just

large enough to admit an end of quick-match. The match is inserted into this hole, and is carried on to another hole at C, bored exactly like the one at A, and at the same distance from the end of the case, but on the opposite side.

The reason for all this contrivance will be readily understood. The Chinese flyer is lighted at the match which enters the hole A. It revolves on the spindle which is passed through its centre, and in a direction opposite to that of its mouth. The composition continues to burn till it reaches the point marked B, when it communicates its fire by means of the quick match with the other aperture at C. If the flyer be required to burn by itself, a piece of touch-paper should be pasted round the end at A, and twisted into a point. If, however, it is to be connected with other pieces, some thin paper should be used, two or three folds thick, and projecting an inch beyond the end of the case, so as to allow the communicating match from the other pieces to be tied in.

In my opinion no Saxon or Chinese flyer, single or double, used singly or in combination, should be without a colour in its centre. For this purpose colours in cases of the one-ounce size will be found sufficient. A case an inch long, independently of its clay end, will burn as long as is required. It may be fixed on in such a position as that indicated at D in fig. 3. It can either be tied on with wire or glued on, or fastened in both ways if considered necessary. It must be connected by quick-match with the end of the case which is fired first.

The colours that I recommend to be used for this purpose are those given at Nos. 21, 22, and 26, in paragraph 50. It is a good plan to fill the cases with at least two colours, if the Saxon is to be fired by itself, so that it may have a varied centre. But if the piece is to consist of more than one Saxon, then it is best to employ a separate colour, which does not

change, with each. I shall say more about the construction of pieces consisting of Saxons presently, when I have described the making of what is known among pyrotechnists under the name of the

DOUBLE SAXON.

64. This, though a larger firework than the single, is quite as easily made, and is more effective. It consists of two cases attached to a wooden centre, such as is represented at fig. 95. It is simply a turned piece of light wood, having ends of such a size as will fit tightly into the Saxon cases. It is about five inches and a half long, and four inches and a quarter between its shoulders. You can procure these in any quantity of Mr. Darby or Mr. Newman.

The cases for double Saxons are made in the same manner as described above for the single Saxons, but are of a different length. The following directions for the division of paper and board will give you cases of a size proper for double Saxons :—

Cut your 60lb. brown paper lengthwise into three equal strips, as represented at the annexed fig. 96. By this division your cases will be about seven and a half inches in length. Your imperial board must be cut, as shown in the illustration at fig. 97, into twelve equal pieces; so that four sheets of 60lb. brown paper, and one of imperial board, will give you material enough for twelve cases, and therefore enough for six double Saxons.

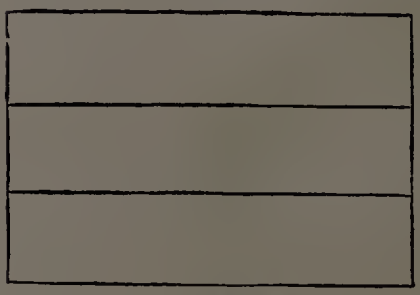


Fig. 96.

The cases are to be filled in the same way as directed above

under the head of single Saxons. After placing your case upon the settle, drive in as much clay as will, when compressed, occupy a quarter of an inch, and see that it is very firm and secure. Then drive in your composition (made from one of the formulas given above) a ladleful at a time, until you have filled the case to within an inch of the end. Drive in another small quantity of clay, and you will then have three quarters of an inch, or thereabouts, of unoccupied space at the end of the case. This is to be filled with the end of the wooden centre represented at fig. 95. When your two cases are filled, *glue them on to the centre,* taking care that they are not likely to come unfastened by any fair means. You will have no trouble in boring the central hole for these, for you buy them already bored in the right manner.

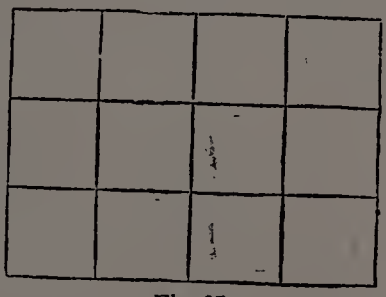


Fig. 97.

But you will have to bore through the case to the composition, to make a vent for the fire. The holes are to be made about half an inch from each end, and on opposite sides, as represented at A and B in fig. 98. After boring the holes, be careful to fill them up again with some of the same composition, leaving only room enough to receive the ends of the quick-match, which should be pressed in with the little instrument represented at fig. 94. This quick-match is first to be put into the hole at A and secured there, and then carried over that end of the case and down the other side to the hole at B, where it is to be secured in the same way. Over the quick-match is to be pasted a piece of thin paper. A strip an inch wide and twenty inches long is what is required for this purpose. This strip is to be pasted all along the match. This will prevent its being injured or ignited at the wrong time.

It is hardly necessary for me to state that the same plan must be adopted with regard to the quick-match that is put to single Saxons. The paper is simply to be pasted over the match in the same way as is done in the case of tourbillons.

A wider strip of paper is next to be cut, which is to be pasted round the end A of the double Saxon, and to project beyond the end, in order to receive the quick-match from other pieces.

In order to attach a colour to the centre of these double Saxons (and they should never be used without a colour), a nail may be driven into the wooden centre, in the position indicated at C, in fig. 93, and the coloured fire case bound to the nail with a round or two of fine wire. The case at C must then be connected by quick-match with the end at A.

All the double Saxons that I have seen have been made in this manner, but there is no reason why they should not burn one end at a time, like the single Saxons. The difference will be that if both ends take fire at once, the pieces will last just half the time that they would otherwise take. The compositions that I have recommended for filling them are quite strong enough to make them revolve well, if only burning at one end; but if the two ends are arranged to burn simultaneously, a much more perfect circle of white fire is produced, and this, I presume, is the object of their always being made to burn double.

In deciding whether they shall burn singly or not, you must take into consideration the questions, How are they to be used? and, With what other pieces are they to burn? You will, no doubt, have plenty of devices of your own making into which these illuminated Saxons will enter. A very little experience will show you their effect, and teach you how long they last, and how to regulate their use.

And here let me give you a hint that you will find very

useful with regard to these, and to all fireworks which can be used in combination. Whenever you ascertain the length of time that any piece—say a Roman candle, a brilliant gerbe, a Saxon, or a wheel-case—is in burning, make a note of it in a book kept for the purpose. It will save you much trouble and calculation, and will add very much to the beauty of your compound pieces, to have a written statement of the duration of any component part of them, so that you may have no excess in any particular, and that it may appear that your design has been made with judgment, and is not the result of a chance mixture of pieces.

I trust that I have left no particular unnoticed in my directions for making these single and double Saxons. If I have, I hope that the principle on which they are constructed is laid down with sufficient clearness to put the mode of its working-out beyond a doubt.

SAXON WHEEL.

65. I now wish to supply a few designs for combinations in which these Saxons, together with other pieces, find a place. The first that I shall give will be that which is called a Saxon wheel. It consists of a wooden framework about three feet in diameter, having six spokes, and into three of these spokes the spindles are driven on which three double Saxons are to revolve. On the circumference of the wheel, cases are tied filled with brilliant fire made from the following formula :—

Meal-powder	4 parts.
Steel filings	1 part.

These cases may be of the one-ounce size, and must burn *two* at a time. This is easily effected by connecting the mouths of the cases, *on opposite sides of the wheel,* with quick-match, and then from the tails of these cases carrying leaders to the

heads of the next two, and so on. The number of cases on the circumference is not a matter of importance. I have drawn six in the sketch at fig. 100. In the centre should be placed a single triangle-wheel, the cases on which may be of the "fixed case" size, spoken of in paragraph 41, but not quite so long—five and a-half inches will be found long enough. The cases on this triangle-wheel may be filled with the brilliant fire. The piece will then require—

6 one-ounce wheel-cases in brilliant fire.

3 triangle-wheel-cases in brilliant fire.

3 double Saxons, illuminated with colours.

You may make this wheel perform in any manner that you choose. I may, however, suggest one order for its performance. I should first light the triangle-wheel, and let its three cases expend themselves. This central triangle must revolve upon the same axis on which the larger wheel turns. Then I should advise you to fire the two connected cases on opposite sides of the large wheel, and let these convey their fire to the other cases which follow them. When four of these cases are consumed (or rather, I should say, when *two couples* of these cases are consumed), fire the quick-match which connects the illuminated Saxons.

You will see that the central triangle is a separate piece, and will not require to be connected with the other part of the design. The Saxons must be connected by quick-match with one another, and must have a leader left by which to fire them. The outside wheel-cases must also have a leader by which they can be ignited at the proper moment. Especial care must be taken that these leaders are not too near one another, or you will probably find your whole piece ignited at one time, and not in the order which you had intended it to observe. The triangle-wheel will, of course, be in front of the other wheel, and so the fire from it will not start the other

Fig. 104.

Fig. 100.

pieces before their time. The best plan for igniting the Saxons at the right moment is to make a fuze to last just the time that the two first couples of wheel-cases take to burn out, and so to convey its fire to the Saxons. These fuzes are a larger sort of portfire, primed at both ends, with a quick-match leading to and from them. The fuze must be lighted by the same leader which fires the wheel-cases, and if it be only of the proper length, will when consumed pass its fire on to the Saxons at the proper time.

In the sketch at fig. 100 it will be seen that the cases at A A are to burn together; those at B B will follow them; and while A A and B B are burning, the fuze at D is also burning, and should last precisely the same time. Then when C C take their fire from B B, the Saxons take their fire from the fuze at D. I hope this is intelligible. I can answer for the beauty of the design if properly carried out. You may put on the three Saxons a red, a green, and a purple fire, which will make a good contrast, and you will further improve your piece by putting a changeable colour on the centre of the triangle wheel. Put the end of the leader E in such a position that it is not ignited by the fire from the triangle.

There is also a very pretty fixed piece, of more simple construction than the above, in which you may use three single Saxons. It consists of three Saxons illuminated, and three fixed cases of brilliant fire. A fuze will be found useful in this piece as in the last, but you can do without it here. Connect the three Saxons with leaders; connect also the three fixed cases with leaders, and carry from these another leader to some point where you can conveniently light it with a portfire. Fire the Saxons (which we will suppose are single ones) and let them burn until one end of each is consumed; then fire the fixed cases of brilliant fire, which should each

have a report at its end. A sketch of the shape of this piece is given at fig. 101.

SAXON SQUARE.

66. The next design that I shall give is known by the name of the Saxon square. The sketch at fig. 99 shows the form of it. It consists of a square wooden frame, used *diamond-wise*—that is with one of its *angles* downwards, and not one of its sides downwards. The pieces required to mount it are as follows :—

8 brilliant fixed cases.

4 Saxons illuminated with colours.

1 illuminated triangle-wheel for centre.

The framework may be about 30 inches square. In the centre place a brilliant illuminated triangle wheel. A *double* triangle will be the best for this purpose, and will make the piece last longer. If the Saxons burn at both ends at once, they must be fired with the brilliant fixed cases; but if one end only burns at a time, the fixed cases may burn with the second halves of the Saxons. The fixed cases should all be reported.

Let two of the cases on the triangle wheel burn first; then let the colour in the centre of the triangle take fire, and burn with the remaining four cases; then let the first halves of the Saxons take fire when the fourth wheel-case begins, and let the brilliant cases come on with the sixth of the wheel-cases, and with the second halves of the Saxons. In this and in all other cases where a triangle, or any wheel is employed, as a centre, it must be brought well forward so that its fire will not injure any other part of the piece.

If it be thought advisable to increase slightly the size and beauty of this piece, place three brilliant fixed cases in the intervals between the Saxons instead of two, and let them be

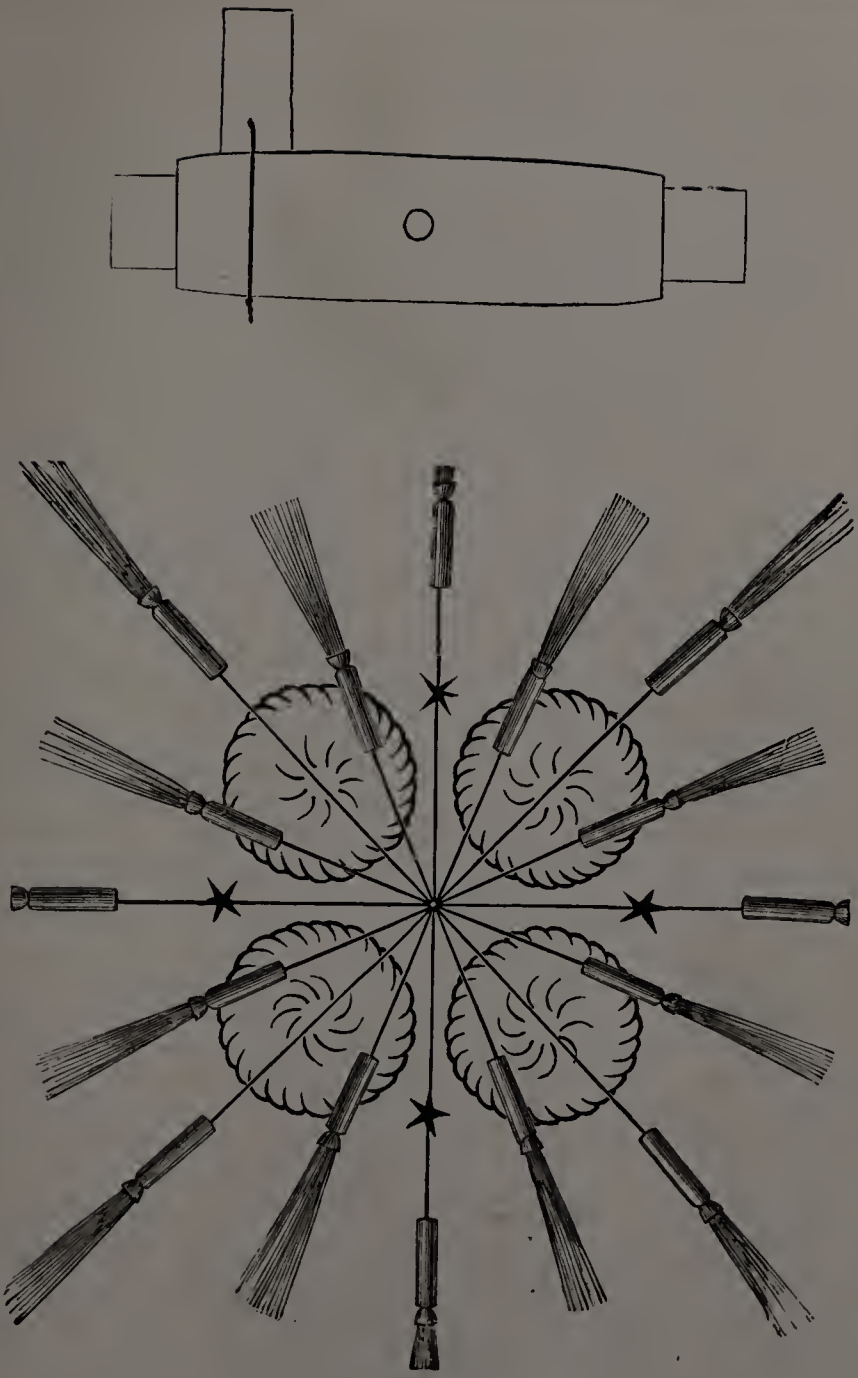


Fig. 102.

fixed so as to form a kind of Prince of Wales's feather in each place.

I now come to a design which I have used, and can, therefore, speak from experience of the beauty of its effect. I employed it at the close of an exhibition, and I can assure you that it makes no inconsiderable finale.

It consists of the following component parts:—

16 brilliant fixed cases reported.

4 double Saxons illuminated.

4 five-pointed stars.

This piece will be much better if it has a brilliant triangle, or double triangle, wheel in its centre. If a double triangle be used, it will begin first and last out through the performance of the piece. The sketch given at fig. 102 will speak for itself as to design, shape, outline, &c., &c. But I may as well suggest in this case, as I have in the others, an order for its changes, or *mutations*, as the authorities delight to call them.

I will suppose that you use a brilliant double triangle-wheel in the centre. This, of course, has six small cases upon it, and should have also a colour in its centre. Fire this wheel first, and let two of its cases be consumed. Then fire the four coloured lights which are to be substituted for the five-pointed stars. Two of these coloured lights may be *green*, and two *purple*. Then when two more of the cases on the triangle are burnt out, strike in the double Saxons and the brilliant fixed cases.

This piece will, of course, take you some time to make, and will require some patience and a good deal of nicety and precision in its arrangements. But it will fully repay you for all the pains that you bestow upon its preparation. I think the colour on the double triangle-wheel had better be purple; those on the Saxons red; the other four colours, as I have said, green and purple.

At fig. 103 I have drawn the wooden centre of a double Saxon to show you an easier way of fastening on your colours. You have simply to bore a hole with a small bradawl through the clay end of the coloured light case, and pass through it a piece of small soft iron or copper wire. The ends of the wire are then bent round the wooden centre, and twisted together tightly at the back.

Fig. 104 represents a settle proper for the making of Saxons. It is to be fixed or screwed into a block, such as I have drawn in the illustrations for Roman candles.

SERPENT MINES.

67. We now come to a very useful and effective feature in pyrotechnic displays, which, although rather short-lived in its performance, produces quite as much aërial decoration as any piece that can be employed. I speak of the mine, whether charged with serpents or crackers.

It would be difficult to find a better single accompaniment to the concluding piece of a small exhibition than a really good serpent mine. But these pieces need not necessarily be used as accompaniments; they may also be made up as separate pieces. Of these combinations I shall speak hereafter.

And first, for the information of those who do not know what a mine is, or what its performance is, I may say that it consists of a cylindrical box, made either of thick paper or iron; and this box contains a number of small serpents having reports; these serpents are placed in the box in such a manner that their mouths may all readily take fire at the same instant, at which instant they are blown out of the box to the height of fifty or sixty feet in the air, where they be-

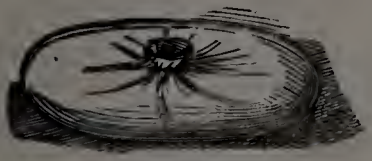


Fig 105.

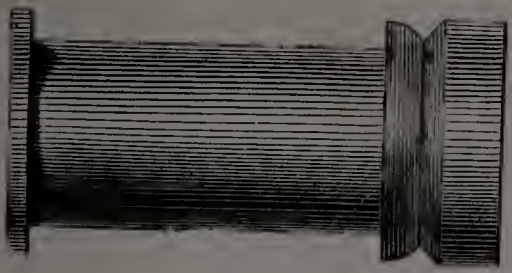


Fig. 109.

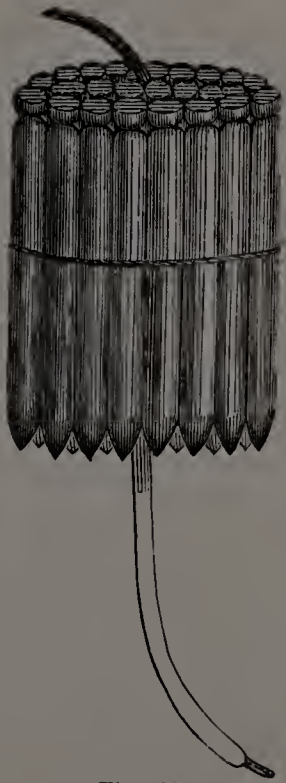
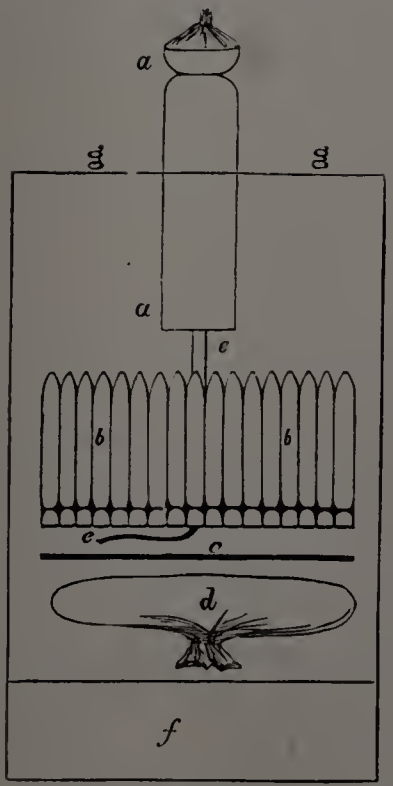


Fig. 107.



Serpents.

Meal Pad.

Powder.

Fig. 108.

Fig. 106.

have themselves in a most lively and somewhat eccentric manner, until a smart pop from each brings their gambols to a close by turning their carcasses inside out.

Now comes the question, "How are we to charm these little serpents into doing as we please?" The following answer to this question will, I trust, leave nothing unexplained or difficult of comprehension.

In the first place, with regard to the serpents themselves, I cannot think that you will find it worth your while to be troubled with the manufacture of them. The work is dirty, troublesome, and rather expensive, because you can do nothing without a choking apparatus proper for this purpose, and when you set in array against these disadvantages the very low price of the serpents, as you can buy them of Mr. Darby, of 98 Regent Street, Lambeth, which is, I believe, at the rate of three shillings per gross, primed and ready for use, I think you will agree with me that the best plan is to wash your hands altogether of their manufacture, and to buy them where you can depend upon their being uniformly good and reasonable in price.

These serpents are generally about two inches and three quarters in length, and are of a very convenient size for the purpose. I will suppose that you have provided yourself with some of these, and that you want to make one of such serpent mines as can be bought at the firework shops.

The first thing for you to do is to decide upon the size of mine that you require. In my opinion, very small mines are not worth making. I should never think of putting less than *two dozen* serpents into a mine. If you will take my advice you will determine upon one or two sizes, and keep to them; you will find this by far the most convenient plan.

The two sizes which I should recommend are those whose

cases are *two inches and a half* and *three inches* in diameter. The latter will discharge three dozen serpents, and will, I think, be found large enough for all purposes.

If you want a former round which to make the case, *or mortar*, as it is called, of the two and a half inch size, you can generally find one ready made at the draper's. They have them as rollers for silks, &c., and the above is one of their sizes. I have found one of these very convenient.

In the next place you must always keep your eye on the look-out for old odd pieces of thick brown paper, or sugar paper, or any thick paper used for parcels, and turn them to account; any old pieces of cardboard may also be worked in. You will want a case or mortar *seven inches long*, and so well pasted and closely rolled that you can hardly bend it with your fingers. Do not spare the paste, nor imagine that you can dispense with the roller board. Well paste the former and all the paper, and when you have finished the mortar, set it by, and do not use it till it is thoroughly dry and hard, but at the same time do not attempt to hurry the drying over, and so warp it and put it out of shape.

You will now have a round hard cylinder of pasteboard, open at both ends. Cut a piece of deal or other wood, of a size that will fit tightly into one of these ends, and *about an inch thick*, and glue it in, to make a firm bottom to the mortar, so that it has no chance of coming out.

Now weigh out one ounce of common gunpowder; such as is sold at the shops at about 1s. per pound is quite good enough for this purpose. Put this into a piece of *thin* paper, and make it up into a neat little flat circular parcel as shown at fig. 105. It should be as nearly as possible the same size as the interior of the mortar. You will find that the mortar of the two and a-half inch size is capable of holding about twenty-eight serpents. But, whatever sized former you use

for the mortar, ascertain how many serpents will be required to fill it, remembering that they are by no means required to fit in tightly; that if they are fitted in tightly your mortar is pretty sure to be blown to pieces, which catastrophe is by all means to be avoided. Having ascertained the number of serpents required, tie them into a bundle with cotton. This will enable you to pass them without any trouble into the mortar. But before putting them in take out the centre serpent, and tie to its neck a piece of quick-match in the manner represented in fig. 106. This match is to convey the fire to the mouths of the serpents, and so on to the packet of powder. When the piece of match has been attached as directed above, replace the serpent in the midst of the bundle. Take notice that that part of the match which projects beyond the mouth of the serpent *is to be uncovered*—that is, is to have its case cut away from it.

Now in order to insure the proper lighting of all the serpents, I have adopted a plan which I have always found successful. The usual plan is to smear the flat side of the packet of gunpowder with meal-powder-paste, and to let the serpents stand mouth downwards upon this. I am well aware that many good mines are made in this way, but I must think that their success is the result rather of chance than of anything else. I have experimented a great deal in this direction. I have fired mines so prepared in a place where I have been able to pick up the remains of the serpents after the explosion of the mines, and I have frequently found serpents that had never taken fire at all. And this fact set me to work upon discovering some new plan. I at once hit upon the cause of former failures, imagining them to be due to the too rapid ignition of the powder, which had not allowed time enough for the fire to be conveyed to the mouths of *all* the serpents. In attempting to rectify this, I naturally enough ran to the other

extreme, and gave them rather too long a time, so that they actually found their way out of the mortar by their own force, and the powder expended itself in a mighty puff just when they were out of the reach of its influence. Of course the serpents only found their way just out of the mortar, and did not produce that lively effect in the air which was intended. So then I had recourse to the plan which I now adopt, and which has never failed me. I take some circles of thin blue paper—such paper as the pyrotechnists use for making into touch paper, which is called *thin blue double crown;* these circles I cut of such a size that they will just pass into my mortar, and I smear them well over with meal-powder-paste made with meal-powder moistened with thin starch or gum-water. One of these circles I place between the packet of powder and the mouths of the serpents. And I find that this arrangement just allows time enough for the fire to be conveyed to all the serpents before the packet of powder is exploded.

You will now have the three principal parts of the mine ready to put into the pasteboard mortar. In order to do this, take your bundle of serpents and hold them *mouths upwards,* as represented at fig. 107, and on their mouths lay the primed circle of thin paper, *meal-powder side downwards.* On this lay the packet of gunpowder, with its *smooth side downwards,* and its tied side upwards. Then taking the mortar, *bottom upwards,* pass it over the whole in the way in which an extinguisher is used. The mine, thus far completed, is now to be turned the proper way upwards, and a knife or pair of scissors passed into it to divide the cotton which bound the serpents together. Care must be taken that this little piece of after-work is not forgotten and left undone, otherwise your serpents will come out in a lump, and will not be able to spread.

But now we come to the case which is to play before the mine is fired. This may be a short case of the one-ounce or two-ounce size, and may be filled with the beautiful old composition called spur-fire. The composition for this is—

Nitre	18 parts.
Sulphur	8 ,,
Lampblack	6 ,,

But there is a great deal of art in preparing this composition. The ingredients require to be well-sifted together, and then rubbed together in a large mortar with a wooden pestle. You must have two or three short choked cases ready while this pestle and mortar operation is going on, in which to try the composition at different stages of its progress. If the ingredients have not been sufficiently rubbed with the pestle, very few of the beautiful spur-shaped sparks will be thrown out. But if, on the other hand, too much rubbing has taken place, the composition will burn too fiercely, and will throw out only drossy sparks. There is certainly a good deal of patience necessary in the preparation of this spur-fire composition, but when properly made it will repay you for all the trouble it has given. It is better to make a good large batch of it at a time. It is said to improve after being rammed into cases a long time.

There is only one disadvantage that I have ever found in this spur-fire, and that is, that much of its beautiful effect is lost unless the spectators are very close to it when it is fired. The scintillating sparks may be caught in the hand without danger.

But there are many other compositions which will answer very well for the beginning case for a mine. For instance, you may use—

Meal-powder	2 parts.
Steel filings	1 part.

Or,

Meal-powder	2 parts.
Iron borings	1 part.

Or,

Meal-powder	4 parts.
Charcoal	1 part.

These compositions may be rammed into either one-ounce or two-ounce cases, and primed in the ordinary way. The tail-end of the case must be left open, in order to insert the end of the match which comes out of the bundle of serpents.

You will next require a circular piece of millboard, of a size that will answer as a lid to your pasteboard mortar. Through the centre of this lid bore a hole with a centre-bit just the size of the case that you mean to insert; and when you have decided how far this case shall project out of the lid, make a mark, and glue the case into the central hole: and when you have made the necessary connection between the tail of the fountain-case and the quick-match from the bundle, the lid is ready to be pasted on. If, however, there is any chance of the mine being knocked about before it is fired, fill in the space above the serpents with waste paper, or, still better, with common wadding, *which does not burn.*

It only remains now to paste a strip of thin paper neatly round the top of your mortar, so as to secure the lid, and then to put some touch-paper to your fountain-case, and the piece is ready for firing.

There is another way of making these mines which you can adopt if you please. Instead of using a short fountain-case, a long one is employed which will reach down to the smeared meal-powder pad. This case has, of course, to pass through the bundle of serpents, and so takes up a good deal

of room among them. If you employ a long case of this kind, you will find it best to use one of the sparkling compositions given above, *and not the spur-fire;* or, at all events, if the spur-fire is used, only half fill the case with it. It is a slow-burning composition, and answers much better in *short* cases of large calibre than in long cases of small bore.

For a mine two inches in diameter the charge of powder should be three-quarters of an ounce. The mortar should be about six inches high.

For a mine two and a-half inches in diameter, and seven inches high, the charge of powder should be one ounce.

For a mine three inches in diameter, and eight inches high, the charge should be an ounce and a-half.

But I must now proceed to tell you of another way of making mines for exhibition purposes which can be fired at any given moment. These are fired from iron mortars. One of these mortars will last a lifetime. The size that I use is that which has a diameter of three inches. The mortar is made of thick sheet-iron, rivetted firmly into the form of a cylinder, with an iron ring round its mouth, and a wood block screwed into its other end for a foot. This mortar has a clear depth of eight inches inside, and is capable of throwing three dozen serpents. The exterior of the iron cylinder is bound round with cord, which is supposed to give it great additional strength. So much for the mortar from which these exhibition mines are fired. The serpents, powder, &c., are contained in paper bags, and have a projecting piece of match by which they are fired. I have a solid cylinder of wood, six inches long, and two and three-quarter inches in diameter, upon which I make my paper bags for these mines A former of this size makes a bag that will contain the three dozen serpents, and will at the same time pass easily into the mortar. The powder, meal-pad, serpents and quick-match

are to be put in precisely in the same manner as that directed above: the powder packet at the bottom, of course, then the meal-pad, then the serpents. After all are inclosed, feel with the fingers for the string that ties the serpents together, and cut through the paper of the bag and this string to liberate them. Your mine will then be ready for firing. Any number of these bags can be fired one after another from the same iron mortar.

You will find a sketch of a pasteboard mortar at fig. 108, showing its contents and the fountain-case. You will find also a sketch of an iron mortar, fig. 109, and bag and serpents, fig. 110; such as I use, which is by far the most convenient way of exhibiting serpent mines.

CRACKER MINES.

68. We will now proceed to speak of cracker mines, another very effective item in exhibition pyrotechny. With regard to the crackers that are employed for this purpose, I cannot think that you will economise at all by trying to make them yourselves. In order to make them all of one uniform size and shape—and these points must be attended to particularly in the manufacture of crackers for mines, otherwise you will be unable to pack them properly in the bags or mortars—a considerable amount of apparatus of rather an expensive kind is required, and is in fact indispensable. The money laid out in the purchase of this apparatus would furnish you with many grosses of mine crackers. If you will be advised by me, you will purchase them of Mr. Darby, whose crackers for this purpose are, in my opinion, exceedingly good. The only difference between mine crackers and those usually sold at the shops for the 5th of November is in their *priming*. Instead of having touch-paper, at which they are lighted, a

Fig. 110.

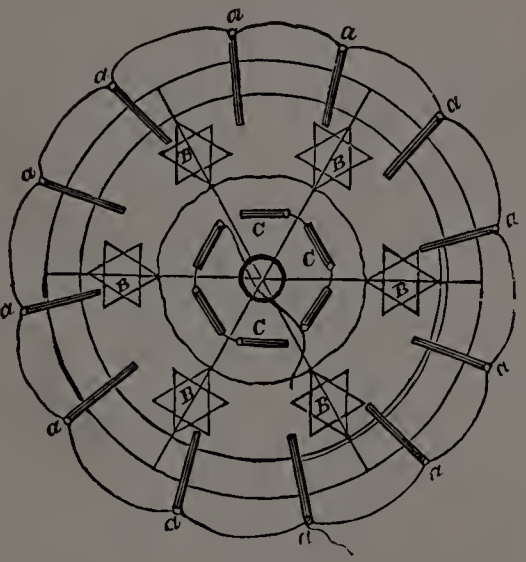


Fig. 115.

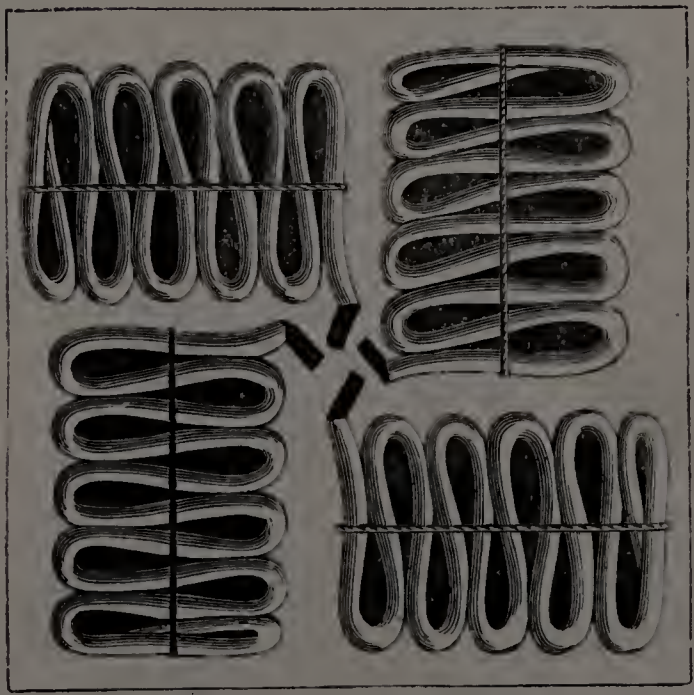


Fig. 111.

piece of bare quick-match is left projecting from the mouth, which, of course, takes fire very readily.

The mortars used for throwing crackers differ from those employed for throwing serpents in being square instead of round. I shall speak only of one size of cracker mortar, because you can at your pleasure fire from it any number of crackers from one dozen to four dozen by adopting my plan of packing them. If you are about to use a pasteboard mortar, you must have a square former made, two inches and three-quarters square and six inches long. Upon this former make a very strong mortar with well-pasted cardboard and thick paper, and let it be thoroughly dry before you use it. Glue into one end of it a piece of wood an inch thick for a bottom.

You will now require just the same kind of packet of gunpowder as was spoken of under the head of serpent mines. This packet may contain an ounce and a-half of common powder. Put it into the bottom of the mortar, flat side upwards; then put a piece of thin paper, smeared over with meal-powder paste, meal powder side upwards, and then proceed to put in your crackers in the following way:—You will find two dozen a very good number for cracker mortars of this size. I frequently use *three* dozen, but this is not necessary. I will suppose that you have determined to use two dozen. Take *six* of these; pack them side by side, so that their primed mouths are arranged in a line; tie them in this position with a piece of cotton; make four of these packets containing six crackers; now put them into the mortar in such a way *that the projecting pieces of quick-match are all turned inwards,* as shown in the drawing at the page of illustrations. The crackers will, of course, all be lying on their sides. Now down the centre of this arrangement lay three or four pieces of bare quick-match, which shall be in immediate

juxtaposition to all the primed mouths of the crackers, and which shall reach down to the meal-powder pad. Thus you will infallibly insure the lighting of all the crackers before the charge of powder takes fire at the bottom.

Over this mine, and as an introduction to it, you can, if you please, place a fountain case, as with the serpent mines, gluing it into the centre of the lid of the mortar, and connecting its tail end with the crackers below.

But the most useful plan for exhibition purposes is to have an *iron* mortar for these mines, made about two inches and three-quarters square (interior measurement), and six inches in depth. Iron mortars should have a very substantial foot of wood. If an iron mortar is employed for cracker mines you must have a wooden former made, about two and a-half inches square and six inches long, on which to form the paper bags that are to contain your powder, crackers, &c. The arrangement of the contents of these bags is precisely the same as that recommended for the filling of the *pasteboard* cracker mortars, except that of course a piece of quick-match must be left projecting from the top of the bag by which the whole is fired. Take especial notice that after placing the parcels of crackers in the bags, as directed above, the cotton which binds each parcel must be cut so as to liberate the crackers, otherwise you will have four parcels of crackers instead of twenty-four crackers making their appearance at the explosion of your mine.

In the page of illustrations, fig. 108 represents a section of a pasteboard serpent mine; *aa*, the fountain-case; *bb*, the serpents; *c*, the meal-pad; *d*, the packet of powder; *ee*, the match passing from the fountain-case through the bundle of serpents; *f*, the wooden block at the bottom of the mortar; *gg*, the lid. 109 represents an iron serpent mortar. 110 represents a mine bag for firing from an iron mortar. 111

represents the arrangement of crackers in a cracker mine. The drawing will be found about the right size, and crackers packed in this manner cannot fail to light.

FIVE-POINTED STAR.

69. The cases are made upon the same "former" on which the quarter-pound rocket cases are rolled. They consist of a piece of 70lb. brown paper and a piece of imperial board. The sheet of brown paper is cut into strips, as represented in the annexed diagram, by which it will be seen that each sheet furnishes enough paper for *six* cases. The imperial board should be divided, as shown in the following sketch, 112, into twelve equal strips—thus: so that two sheets of 70lb. brown paper and one of imperial board will give material for one dozen cases for five-pointed stars. The paper and board must be well pasted, and the rolling-board used unsparingly, as cases for this purpose cannot be too strong and hard.

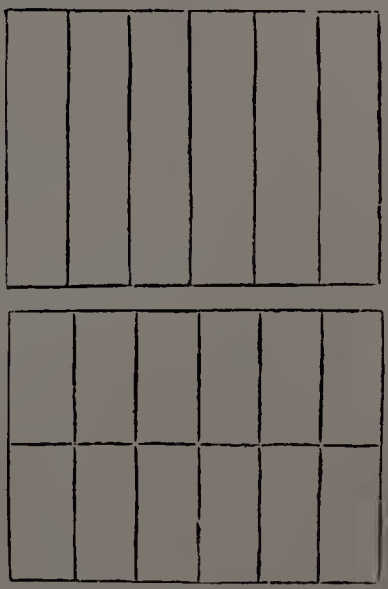


Fig. 112.

Fig. 113

The common plan for filling these cases with composition is simply to put them on the same settle on which quarter pound tourbillons are rammed, and to drive into the lower end of them about half an inch of clay, very solid, and to ram in the composition upon this until it rises to such a height

as will enable the star to burn as long as the piece or pieces with which it has to keep time. But I think a much better plan is the following:—Procure a turned drift of box, or some *hard* wood, about five inches long in its straight part, with an end as represented at fig. 113. Put a ladleful of clay into the case when it is upon the settle (the ladle used for filling quarter-pound rockets is meant), and drive down the clay with the conical end of the drift, by which means you will have a hollow clay cone formed in the end of the case. Now ram in your composition, which may be made from either of the following formulas:—

FOR FIVE-POINTED STARS.

No. 1.

Nitre	16 parts.
Sulphur	6 „
Meal-powder	4 „
Antimony	2 „

No. 2.

Nitre	16 „
Sulphur	8 „
Meal-powder	6 „
Antimony	4 „

No. 3.

Nitre	16 „
Sulphur	8 „
Meal-powder	4 „
Antimony	3 „

It will be best to decide first of all which of these compositions you prefer, and to keep to that, remembering that five-pointed stars are never used singly, but only as parts of compound pieces, and that in order to produce their proper

effect, they ought to last just for a certain time and no longer. By keeping to *one* of the compositions given above, you will be able to time them better. I cannot give any directions for the quantity of composition to be driven in—this must depend entirely upon the part which it is intended that the stars should play in the piece for which they are made, and can be decided only by actual experiment. The composition will not require to be driven very hard.

You will by this time be beginning to wonder how a case filled in the manner described above is to make a five-pointed star. Well, there is no great difficulty in achieving this end. Provide yourself with a gimlet which will make a hole about one-eighth of an inch in diameter, or rather more; also with a pair of compasses the legs of which can be secured at certain distances from one another. Let the points of the compasses be exactly such a distance apart that they will represent *one fifth of the exterior circumference* of the case—that is, so that they will exactly go round the case in five strides, finishing at the point from whence they started. When you have thus adjusted your compasses, make them perform their five-stage journey *round that part of the case inside which is the hollow clay cone*, about half way between the point and base of the cone, and wherever the points of the compasses touch, there make a mark by pressing the point into the case. You will thus have divided the circumference of the case into five equal parts. Now at each mark made by the compasses bore a hole gently with your gimlet, which should be a sharp one, taking care that you only bore through the case and the clay, and disturb the composition as little as possible. In order to prime the case, fill the hollow at the end of it, which was occupied by the top of the settle, with wetted meal-powder, and when this is dry, pass across it a piece of bare quick-match, the ends of which should be long enough to be tucked

into two of the gimlet-holes, and which will convey the fire from the priming to the composition inside the case. Then cut some pieces of thin paper (such as double crown) three inches wide, and long enough to go twice round the case, and paste one of these on the case just below the gimlet-holes, so that the paper covers up gimlet-holes, priming, match, and all, and projects an inch and a half or thereabouts beyond the primed end of the case. This projecting paper serves to contain the end of the encased match which is to connect the five-pointed star with other pieces.

The best method of fixing these stars on the frames for which they are required is to have projecting from the frames wooden pegs of such a size that the unprimed end of the case can be squeezed tightly over them or glued on to them. I should have stated that when the proper amount of composition has been inserted, a little clay should be driven on the top of it for the sake of security, and there should be not less than three-quarters of an inch of unoccupied case beyond this clay. Into this unoccupied space the pegs mentioned above should be fixed.

Five-pointed star-cases must, of course, be placed horizontally, with their primed end towards the spectators; and when fired they will, or should, present an appearance of this kind, the burning composition protruding its tongues of white flame through the holes made by the gimlet.

Fig. 114.

In your anxiety not to disturb the composition with the gimlet, do not run into the other extreme, and leave the *clay unbored.* And see that there is sufficient clay beyond the point of the cone to prevent the combustion from finding vent there.

The object of the conical clay head to the case is that the fire may not burn the holes larger. If the holes were simply bored through the paper case they would be burnt much larger than they were originally made. Nevertheless, if it be thought too troublesome to make the hollow clay cones, as I have suggested, a very fair five pointed star may be made by driving in a flat end of clay, and boring just below it into the composition.

It is possible to make the cases for five-pointed stars of iron tubing, such as ordinary gas-tubing, about the same size in bore as the paper cases, the manufacture of which I have described above. Half-a-dozen iron cases, open at both ends, with the five holes drilled at equal distances round their circumference, and about an inch from the end, will be found very handy, because they are indestructible, can be used any number of times, and after use have only to be laid in hot water, and they can be washed as clean as when new. It will be necessary to tie something round the holes while the composition is being driven in. The ends, of course, are made with clay.

But let me here caution you to be very careful in the use of iron cases. If quicker compositions than those given above are employed, there is danger of the case being blown to pieces. If this should happen it would result in the most serious injury to any one who might be in its way. And therefore it will be advisable, if you think of using iron cases, to fire your experimental five-pointed star at a great distance from where you stand, taking care that no one is near it. It will probably go well; but there is a risk attending the use of iron cases which makes them less safe than those made of paper and board.

I trust that these directions will enable you to prepare a satisfactory five-pointed star.

It now remains for me to furnish you with some designs for exhibition pieces, and to describe the manner in which they are to be made up.

EXHIBITION PIECES.

70. If it be thought desirable to have ready a variety of frames which can be fitted up at a moderately short notice, some of the following will be found useful, and capable of being mounted with fireworks in many effective ways :—

In the first place there is the large vertical wheel, the frame of which is described at fig. 115. This should be not less than four feet in diameter, and should turn on an iron spindle made of three-eighths of an inch rod. The following is a good useful sort of spindle for large wheels (fig. 116), being very steady and easily fixed to your post. *AA* represents the post, which should be ten feet out of the ground. *BB* represents the spindle, which has an iron collar at *C* and a large thumbscrew at *DD*. The collar is fixed to the spindle, and is placed against the face of the post. The thumbscrew is screwed up tightly at the back of the post, and keeps the spindle firmly in position. The other end of the spindle may be "tapped" for a short distance, and have a small "nut" to fit it, in order to keep the wheel from working off ; this, however, is not of much importance, as a piece of cork tied on will do as well.

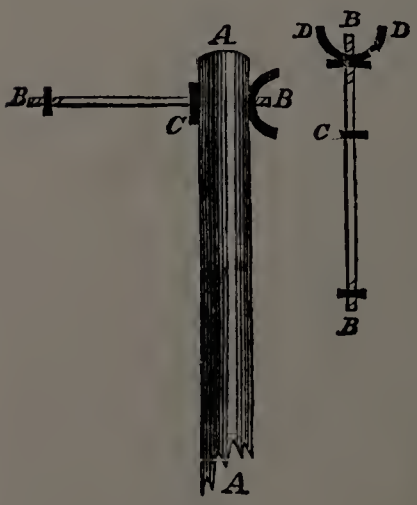


Fig. 116.

The wheel should have a nave of hard wood, through which

a hole is bored to admit the spindle. And in the case of all vertical wheels, it should be borne in mind that they will revolve much more lightly and easily if the spindle does not touch the wood of the nave at all, but works through two iron or brass plates, fastened one on the back and the other on the front of the nave, and having holes drilled in them of a size proper to admit the spindle without too much "play." The working of a large wheel will be very much more satisfactory if this plan be adopted, and the wood of the nave be not allowed to touch the spindle at all.

For a wheel of four feet in diameter there should be six spokes, to the ends of which is fastened a strong ash or beech-wood hoop. There should also be another wooden hoop six inches nearer to the centre of the wheel, as is shown at fig. 115. The pieces with which I have there represented the wheel as fitted up are as follow:—

a a a a are twelve brilliant reported "fixed cases," which, as will be remembered, are cases having an interior bore of seven-sixteenths of an inch, and reported with a gun-charge of powder at their end, and filled with brilliant fire. Each of these is fastened to the two outer wooden hoops at a slight angle, and all their mouths are connected with quick-match, the end of which is to be brought to the bottom of the wheel and tied to the post which carries the wheel. This tying will have the effect of steadying the wheel until the time arrives for firing the fixed cases.

B B B B are six triangle wheels, the turning cases of which are filled with brilliant fire, and carrying each a colour. The cases need not be larger in diameter than the "fixed cases" mentioned above. In my sketch I have described them as *double* triangle wheels, but the artist must decide for himself whether they shall be double or single—*i.e.*, whether they shall have six or three cases apiece.

In front of the nave of the wheel is placed a much smaller vertical wheel (*C*) on the same spindle. This may be made to carry six turning cases of brilliant fire, and as many colours as you think proper. The cases may be made to burn singly or doubly (*i.e.*, two cases at a time upon opposite sides of the wheel).

Supposing the wheel represented at fig. 115 to be mounted with one smaller central vertical wheel, with six cases and colours, six small brilliant single triangle wheels with colours, and twelve brilliant reported fixed cases, the way in which it should be fired is this :—Connect together by quick-match all the single triangle wheels, and let the end of this match be secured where it can be found with readiness, and where also it is out of the reach of sparks. I will now suppose the cases on the central wheel to burn singly, in which case fire—

1stly. The central wheel, and when three of its cases are all but burnt out, put your port-fire to—

2ndly. The match which is to start the six single triangle wheels. When these are half burned out (*i.e.*, when about a case and a-half is consumed on each) fire—

3rdly. The quick-match which connects all the reported fixed cases on the circumference of the wheel, and you will then have a revolving piece of fire nearly twelve feet in diameter, of which the sketch at fig. 119 is intended to give you an idea.

The framework of this piece is, as you will at once see, capable of being fitted up in many other ways. For instance, instead of triangle wheels, you might use Saxons; instead of a central illuminated vertical wheel, you might have a six-pointed star in white lance work. In fact, there is hardly any limit to the variety which might be produced if the artist will only acquaint himself with the value and adaptability of

the single pieces which are treated of in the former numbers of this series of papers.

We now come to the last page of illustrations, where is described a set-piece known by the name of the lattice-work piece (fig. 121). This may be made either with 24 brilliant reported fixed cases and 6 coloured fires, or with 36 fixed cases and 9 coloured fires. The sketch is made to represent the arrangement as it should be for 36 cases and 9 colours. If used with only 24 cases, and 6 colours or five-pointed stars, it will be *a large piece*, and quite effective enough for a display of ordinary pretensions. It is made by fastening brilliant reported fixed cases to squares of wood, and fixing these squares at equal distances from one another, so that the fire from the cases represents lattice-work.

Provide for this purpose as many squares as you require, half-an-inch thick and seven inches square. To each of these fasten the reported ends of four brilliant fixed cases by boring holes on each side of the cases through the wood, and fastening them by means of wire or string in their places. In the centre of each square fasten either a coloured case or a five-pointed star. Each square, when mounted, will be like the adjoining sketch.

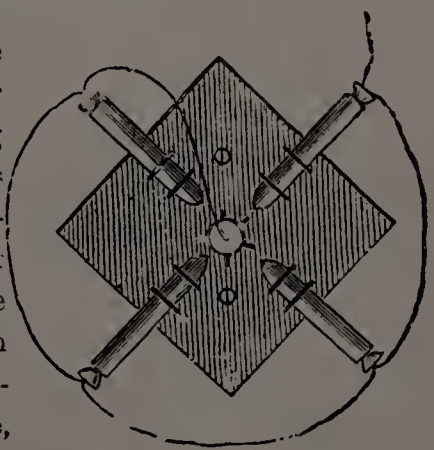


Fig. 120.

The distance from one another at which these wooden squares should be fixed must depend upon individual taste; you must remember that the farther apart you fix your upright posts in the ground the longer the posts must be, as you cannot spread the piece sideways without increasing its height,

A good distance apart for the posts will be three feet six inches. If this distance be observed, and nine squares are used, you will require posts at least fifteen feet out of the ground; but if six squares are used, which I think you will find effective enough, posts twelve feet out of the ground will be sufficiently high. At fig. 121 you will see that, for additional effect, I have placed at the top of the two side-posts large gerbes. I should make these *certainly not smaller than the quarter-pound size*, and as long as the fixed cases employed. Fill them with—

Meal-powder	3 parts.
Iron-borings	1 part.

These gerbes must be connected by quick-match with the squares which are on the same posts with them. At the top of the central post I should place either a "simple horizontal" or a "capricious" wheel, the manufacture of which I described in my paper on wheels. The capricious wheel will be the most effective.

In order to prepare the piece for firing, bring all the pieces of match which are to convey the fire to the brilliant squares and gerbes to a point in the centre of the piece, leaving them long enough to be tied together in a bundle round *the case* of the match. Beyond the point where the match-cases are all tied together leave at least six inches of each quick-match bare, and tie these bare pieces together in one or two places. Unless this precaution is taken, some of your squares will have a good chance of not being fired at all. But by this means they can hardly misfire. The object is to give all the bare-ends of match time to take fire *before the fire reaches the covered part of any* of the matches.

Fig. 121 will give you some idea as to what the lattice-work piece should look like before it is fired. To fire it, light

first the piece of quick-match which hangs from the capricious wheel. When *four* cases on this wheel are burnt out, light the collected ends of quick-match in the centre of the lattice-work. *These ends must on no account be exposed until they are to be fired;* therefore some paper must be wrapped round them, which can easily be removed. At once your brilliant cases, stars, and gerbes will be ignited, and will burn while the remainder (which is the best part) of the capricious wheel is going through its revolutions. You will then, if all goes right, have such a piece as is represented at fig. 122.

My next illustration shows a simple but beautiful piece, having for its centre a wheel such as I have described in my papers on coloured lights, lances, &c., and consisting of four double triangles executed in white lances, and a large four-pointed star in brilliant fire. Fig. 123 represents the frame-work mounted, as it appears before firing. This framework is simply four arms, made of deal, and fastened into a solid centre; the arms may be five feet long. At the extremities of these arms are fastened four double triangles made of deal lath or any light material. Upon these little frames fasten white lances, by driving in short pieces of iron-wire into the woodwork, and after boring the closed end of the lances with a very small awl, sticking a lance upon every wire-pin with the mixture of glue and red-lead recommended in former papers. Then clothe the double triangles with quick-match in the usual way, and connect them all. In the next place fasten on each of the arms, at a suitable distance from the centre of the piece, two reported brilliant fixed cases, in the manner indicated in the sketch; clothe these with match, and connect them.

For the centre of the piece take the wheel with dangling colours, explained under the head of coloured lights, and fit it up carefully. The piece will thus be ready to be fixed to its

post. To do this you will require an iron spindle something like the one I have recommended for the four-feet vertical wheel, with this difference—that the framework of our present piece must not revolve, but remain stationary; the centre wheel alone is to revolve, which it will do well enough on such a spindle. But remember that all vertical wheels used as centres to large pieces *must be brought well forward before the rest of the piece*, otherwise the sparks from them will fire the other parts before their time.

I will now suppose that you have the piece represented at fig. 123. You must first start the central wheel, which should be connected by match with the triangles at the extremities of the arms. These will then burn together until a case and a-half of the central wheel is consumed, at which time strike in the eight brilliant fixed cases, and this done your piece will take the form represented at fig. 124.

We now come to the last of my designs, by which is represented at fig. 117 a large set-piece worthy of proving a finale to any exhibition, and at the same time by no means difficult of preparation.

The framework of this piece consists of a solid wooden centre, into which are secured six arms made of deal, in such a manner that they are like the spokes of a large wheel in their arrangement. The arms for this piece, and for that represented in fig. 123, should be five feet in length, two inches in width, and an inch full in thickness. For the sake of economy I think you will find it well to make one centre do for both these pieces, by having grooves cut in one side of it to hold six arms, and in the other side for four, as you would never require *both* these pieces in the same exhibition. The grooves in my framework are about half-an-inch deep on each side of a circular flat centre of oak, two inches in thickness and twelve inches in diameter; they impart greater steadiness

to the arms than could be gained by screws alone. So much for the framework, which you will see is, when put together, ten feet in diameter, and can always be taken to pieces for the purpose of economising space. If you have six arms made, you can use either four or all of them at pleasure.

Now for the pieces with which this framework is to be mounted.

In the centre there should be a large double triangle frame, mounted with white or coloured lances. The six laths of which this framework should be made should be each three feet six inches long, and about five-eighths of an inch square. The lances placed upon them should be not less than three and a-half inches apart. These must all, of course, be connected by quick-match. The six angles of the double triangle should rest upon the six spokes of the framework of the piece. At a distance of an inch or two outside each angle should be fixed a five-pointed star, and close to it two brilliant reported fixed cases, which must be connected by quick-match, and fastened at such an angle with the framework that their fires may meet at a point between the six triangle wheels, which, lastly, are to be placed at the extremities of the long arms. The cases on these wheels are to be filled with brilliant fire, and each wheel is to carry a colour in its centre.

To fire this piece begin with the central double triangle, and when this is well-lighted, fire the six triangle wheels and five pointed stars, and when one case of the triangle wheels is consumed, fire the twelve brilliant fixed cases, and your piece will be of the shape given at fig. 118.

With this piece I close my "Papers on Pyrotechny." I trust that I have left nothing unsaid which could make the directions given for these pieces more clear, and I hope that many an amateur will soon have arrived at such a state of proficiency as will enable him not only to prepare such pieces

as these, but any variation upon them. No piece should be used as a finale to any exhibition unaccompanied by two batteries of Roman candles containing coloured stars. These so-called "batteries" consist simply of four, six, or any number of Roman candles fastened to upright posts at such an angle that they may throw their stars over the centre of the piece from each side of it. Any number of serpent or cracker mines that can be brought to bear while the finale is in *full* force will greatly enhance the effect, if fired from behind it.

In conclusion I believe that, in any village even, were any one to manifest a desire to become a successful pyrotechnist, and to interest his intelligent neighbours in his adopted art, he would find that in most cases they would lend a hand, and show an activity in the preparation of a public exhibition to a degree which no one who has not tried the experiment would anticipate. Many a long evening might be shortened by discussion with the artisans of the place as to the best mode of making what is usually known as a "grand flare-up" for Christmas Eve or New Year's Eve. And if I am not very much mistaken, such a discussion would prove at least as interesting to any inquiring mind as the very desultory and questionable source of information commonly called Penny Readings, at which it is the fashion to spoil so much good writing by bad reading, and so much good music by bad singing. It cannot but be evident that any exhibition of fireworks in a place must be to a certain extent public; all who can will do their utmost to get their chins above the level of the walls or fences which are intended to make any exhibition private; and quite rightly too, in my opinion. Though no longer a boy, I should do the same now, unless I had reason to believe that the "grand display" was about to consist of a certain number of dozens of squibs, crackers, and pin wheels, fired as fast as circumstances will allow, considering the num-

ber of times that the lantern is blown out by the incautious application of one or other of the above-named combustibles to its flame. In the case of *experiments*, which *must* be made before every exhibition, I think that the more private one can keep *them* the better. But if there is to be an exhibition, why not let every one who can, not only see it, but give assistance in its preparation? You will by this means not only insure a much more real interest in your success, but gain the satisfaction of having proved to many an intelligent villager the important truth that he is capable of doing something for which he had never suspected the slightest capability.

These hints I throw out merely as suggestions. They have been acted on with the most satisfactory results, and I feel sure that they may be turned to account; but everything will depend, of course, upon the manner in which the plan is worked out, and the spirit felt by those whose aid it is proposed to engage. I need only add to these remarks that if it can be shown that my work has done anything towards making pyrotechnic recreation more general, reasonable, and possible than it has hitherto been, I shall consider myself amply rewarded for the time that has been spent (much to my own gratification) in making and recording the results of my experiments.

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